RI 6828

NONPEGMATITIC BERYLLIUM OCCURRENCES IN ARIZONA, COLORADO, NEW MEXICO, UTAH, AND FOUR ADJACENT STATES

By Henry C. Meeves

* * * * * * * * * * * report of investigations 6828

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF MINES
Walter R. Hibbard, Jr., Director

RI 6828

This publication has been cataloged as follows:

Meeves, Henry C

Nonpegmatitic beryllium occurrences in Arizona, Colorado, New Mexico, Utah, and four adjacent states, by Henry C. Meeves. [Washington] U. S. Dept. of the Interior, Bureau of Mines [1966]

68 p. illus., tables. (U. S. Bureau of Mines. Report of investigations 6828)

Includes bibliography.

1. Beryllium ores—U. S. I. Title. (Series)

TN23.U7 no. 6828 622.06173

U. S. Dept. of the Int. Library

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NONPEGMATITIC BERYLLIUM OCCURRENCES IN ARIZONA, COLORADO, NEW MEXICO, UTAH, AND FOUR ADJACENT STATES

by

Henry C. Meeves [1]

ABSTRACT

The nonpegmatitic sources of beryllium in Arizona, Colorado, New Mexico, Utah, and four adjacent states investigated by the Bureau of Mines are described. The investigations included 155 properties from which over 6,200 rock samples were collected; more than 5,500 samples were analyzed by the nuclear beryllium-detection technique. Twenty-four of the properties examined had rock containing more than 0.10 percent BeO. Many of the beryllium determinations were made in the field with portable detection instruments by direct scanning of outcrops and by testing samples of rock brought to the instrument. The large domestic resources of low-grade nonpegmatitic beryllium ore in Utah, which were discovered by private enterprise and which respond favorably to small-scale treatment processes, may come into commercial use and thus reduce the dependence of the United States on imported beryl.

INTRODUCTION

The light, metallic element, beryllium, was identified in 1828, but its biggest use, as a hardener of copper, did not develop until the 1930's. Uses for beryllium alloys, especially beryllium-copper, increased rapidly during World War II. Shortly after the war, beryllium attracted appreciable interest as a moderator and reflector material for reactors. Since the late 1950's, the focus has been on numerous potential uses of beryllium in high-speed aircraft, missiles, and spacecraft. As a result of these new applications for beryllium, the metal has undergone extensive research and development and some of the work is still in progress.

From 1954 to 1962, the Government bought domestically produced beryl at premium prices and under the Domestic Beryl Purchasing Program, although the purchase program ended in 1962, the Office of Minerals Exploration (OME) of the U.S. Department of the Interior continues to offer financial assistance of up to 50 percent of approved costs to explore for all types of beryllium.

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Work on manuscript completed June 1965.

Beryllium, at present, is derived from hand-sorted beryl. In the United States, this mineral has occasionally been obtained alone but more frequently as a byproduct from the mining of feldspar, mica, and lithium. Elsewhere in the world, beryl is obtained from pegmatite deposits comparatively rich in this mineral. These foreign deposits can be worked profitably because the cost of the hand labor required by current mining practice is low. The growing interest and demand for beryllium and the dependency of the U. S. beryllium industry on imported beryl inspired various agencies of the Government and many private organizations to investigate the domestic beryllium potential. Because the potential of domestic pegmatite deposits is limited, attention turned to investigating the possibilities of beryllium in nonpegmatite deposits.

Occurrences of beryllium in nonpegmatitic rocks have been known for many years, but none were considered minable resources until recently when several promising new deposits of beryllium were discovered. For a period, the Badger Flats area, Park County, Colo., yielded commercial-grade beryl, but recently output has been low-grade material. Some nonpegmatitic beryllium deposits in Utah, New Mexico, and Nevada are low grade but extensive and could be mined by large scale methods. With development of economic processing, some of these large, low-grade deposits could become a significant domestic reserve and conceivably make the Nation independent of imported beryl.

The Bureau of Mines turned to investigating nonpegmatitic beryllium deposits in 1959 as part of a nationwide study of overall beryllium resources that began in 1956. The first work was mostly confined to areas of granitic rocks and tactite zones, especially those containing tungsten. Later studies by the Government and by private investigators showed that beryllium also occurred in other mineral and structural associations; these include--

A. Areas of volcanic extrusives containing fluorite, as at Spor Mountain, Utah.

B. Deposits containing both manganese and zinc, as at Iron Mountain and Victoria Mountains, N. Mex., and the Mineral Range, Utah.

C. Deposits occurring along zones of intensive faulting and alteration, as at Warm Springs, N. Mex., and Gold Hill, Utah.

Nonpegmatitic deposits of beryllium examined during the Bureau's work in Arizona, Colorado, New Mexico, and Utah are described in this publication. Reconnaissance in Nebraska, North Dakota, South Dakota, and Wyoming did not disclose significant occurrences.

ACKNOWLEDGMENTS

U.S. Geological Survey Professional Paper 318 (40)[a] was used to familiarize Bureau personnel with known nonpegmatitic beryllium-bearing occurrences

[a] Underlined numbers in parentheses refer to items listed in the Bibliography of this report.

and with rock formations that might have a beryllium potential. In addition, many prospectors, claim owners, mining engineers, and geologists also provided information on potential beryllium sources and suggested properties that might merit sampling. W. R. Griffits, W. N. Sharp, and C. C. Hawley, geologists, Federal Geological Survey, supplied valuable information the geology of beryllium deposits. The assistance of W. W. Vaughn, Federal Geological Survey, and Dr. J. M. Birmingham, Boulder Scientific Co., Boulder, Colo., in training Bureau personnel in radiation safety and the use of nuclear beryllium detectors is acknowledged.

METHODS USED FOR DETECTING BERYLLIUM

Promising samples of rock which were collected by Bureau engineers in Area V prior to 1959 were tested in the Denver laboratory by one (28) of four qualitative spot-test methods (2, 20, 33). Samples which contained beryllium were sent to the Bureau's Salt Lake City Metallurgy Research Center for chemical analysis. Samples which showed no beryllium by the spot tests were combined into groups of 10 or more and sent to Salt Lake City for checking beryllium by chemical analysis, as some of the samples contained minute quantities of beryllium and required more sensitive methods to detect the element. Approximately one of every four samples was also tested by spectrographic analysis at Salt Lake City for cesium, rubidium, columbium, lithium, scandium, or other possible associated metals. Later, when nuclear detection devices became available, samples were analyzed in the field and those which contained significant beryllium were rechecked in Denver with laboratory nuclear detection equipment. Some of these samples were sent to Salt Lake City for spectrographic analysis and to check Denver results. Many beryllium determinations were made by scanning outcrops directly without actually taking a sample (fig. 1).

Approximately 6,200 samples were tested during 1956-63, of which nearly 5,500 samples were tested between July 1959 and October 1963.

NUCLEAR BERYLLIUM DETECTION

Principles

The technique of nuclear beryllium detection is based on the gamma-neutron (γ, n) reaction in which the natural beryllium isotope, Be^9, emits fast neutrons when bombarded by high-energy gamma radiation. The neutron flux produced can be detected electronically. The gamma radiation is supplied by antimony 124 (Sb^{124}), an artificial radioisotope produced in an atomic pile.

The usefulness of the (γ, n) reaction in determining beryllium stems from certain characteristics of the reaction:

a. The reaction can be induced in any mineral, chemical, or other material containing beryllium.

b. The reaction is, for all practical purposes, specific for beryllium even though some of the gamma radiation from Sb^{124} has an energy level of 2.3

FIGURE 1. - Scanning Beryllium-Bearing Stringers (White) in Alder Schist With Portable Beryllium Detector, Breadpan Area, Gila County, Ariz.

million electron volts (mev), which will induce neutron flux in deuterium. However, deuterium is not likely to be encountered in beryllium exploration. A few elements, including boron, cadmium, samarium, and gadolinium, have a high cross section for thermal neutrons and, if present in a sample under test, may capture some of the neutron flux. Results obtained in this case would tend to be low. However, these elements are not likely to be present in beryllium ores in sufficient concentration to be a serious interfering factor.

c. The induced neutron flux can be used to measure the beryllium in a sample when conditions are constant; the flux is proportional to the beryllium content. Analytical results are arrived at by comparing the measured neutron flux from unknowns with that in standard samples of known beryllium content.

Design of Instruments

A nuclear beryllium detection instrument is a combination of standard electronic components, sensitive to the neutron flux from the (γ, n) reaction in beryllium, that will convert the flux to electrical impulses, then amplify and record the converted signal as a series of pulses, or counts. The accumulated count is a measure of the beryllium content of samples under test. It is also a function of source strength, geometry of sample exposure, and efficiency of instruments as well. Obviously, all factors affecting measurement of neutron flux, other than beryllium content of the samples under test, should be maintained at a constant level so that the observed count will be representative only of sample content and not of another variable.

The essential parts of the beryllium detection devices used in Bureau of Mines work are--

a. A source of high energy gamma radiation (above 1.6 mev).

b. A detection unit to produce and amplify electrical impulses from neutron flux.

c. A register to record the impulses fed to it from a detector.

d. A power source for the instrument.

e. A housing design to combine source, detector, and counting device in a safe, workable ensemble.

Antimony 124 produces gamma radiation having the necessary high energy for the (γ, n) reaction. For use in beryllium detecting instruments, Sb^{124} is normally furnished in sealed capsules about one-half inch long and one-fourth inch in diameter with an initial activity of 50 to 100 millicuries (mc). Acquisition and use of Sb^{124} is subject to licensing by the Atomic Energy Commission (AEC). The encapsulated sources are shipped by the vendor in lead containers, or castles, conforming to Interstate Commerce Commission (ICC) specifications. A capsule for a portable instrument is secured to a lead source carrier, and remains attached to it while in the possession of the user. The capsule and carrier are attached to the detecting instrument for actual use and stored in the shipping container at all other times. A source for a laboratory instrument is transferred by licensed personnel from the shipping container to a source carrier built into the instrument, where it remains until depleted. Depleted sources are returned to the vendor, also in a shipping container.

Antimony 124 has a half life of 60 days; that is, the radioactivity declines by one-half every 60 days. At the end of two half lives (120 days), activity will have declined to a quarter of the original level, and the source must be replaced if high sensitivity is to be maintained to test low-grade samples.

The detection unit usually has several components housed in an aluminum case:

a. A lead shield that reduces direct gamma radiation from the source but allows neutron flux to pass freely. The shield in a portable instrument is an integral part of the source carrier rather than the detector unit.

b. A moderator to slow the fast neutrons emitted by the (γ, n) reaction because detectors are much more sensitive to slow (thermal) neutrons. A compound containing hydrocarbons, paraffin for example, is an excellent moderator for fast neutrons.

c. Several types of neutron-sensitive detectors are available. One type is a boron-enriched zinc sulfide-phosphor that emits light flashes (scintillations) in proportion to the neutron flux received; the phosphor disc is optically coupled to a light-sensitive photomultiplier tube that amplifies the signal received. Another detector in use is a boron trifluoride tube, a type of Geiger tube, that produces an amplified signal proportional to neutron flux received. This detector has some advantages as it is more selective to neutron flux than scintillation phosphors.

d. An electronic biasing or discriminating circuit. Detectors are sensitive to cosmic and gamma radiation as well as to neutron flux, and all of the gamma radiation cannot be cut out by shielding. However, gamma rays produce electrical impulses of lower value (pulse height) than do neutrons or cosmic rays. By proper biasing or adjustment of a discriminator circuit, the lower energy gamma pulses entering a detector can be prevented from registering in a counting mechanism. Cosmic rays and neutron flux will register together, and the background, as measured in a separate cosmic background determination, can be deducted from the registered count to arrive at a representative neutron count. Cosmic background is practically eliminated when an instrument is used underground.

e. A counting register. This can be a standard laboratory scaler, rate meter, or some other counting device triggered by electric impulses fed to it from a detector. A small solenoid-actuated counter is employed in portable instruments.

f. A power source. The power source in laboratory devices is usually standard 115-volt AC supplied through a voltage regulator for stability. In portable instruments, radio-type dry cells or mercury batteries are used. The latter are preferable because their voltage output is more stable during useful battery life.

The physical design of beryllium detectors provides an arrangement for combining source, detector, and counting device in a convenient assembly. In a laboratory instrument, the components remain assembled. In a portable instrument, the units are disassembled for storage and transportation. In portable instruments, the source is placed between the sample and the detector. In laboratory instruments, the sample is usually between the source and the detector.

The (γ, n) reaction has a short range and the gamma source must be brought within 2 inches of the sample, preferably closer. The reaction will take place in beryllium-bearing material 2 inches or less below a rock surface to which the source is applied. In scanning rock exposures directly with a portable instrument, many individual readings must be taken in order to examine a rock surface in detail.

The neutron flux produced in the (γ, n) reaction is emitted in every direction, but less than one half of the total flux is captured by the detector in Bureau of Mines instruments. In a laboratory instrument, the geometry of exposure could be improved by surrounding the source with the sample and placing both source and sample within a ring of boron trifluoride detecting tubes.

Interpretation of Nuclear Measurements

The (γ, n) reaction is a random event, as is cosmic radiation. It follows that measurements of such events must be interpreted statistically for meaningful results; therefore, a large accumulation of neutron count is necessary for statistical accuracy. Count accumulation can be improved in several ways because neutron flux is a function of source strength, geometry of sample exposure, detector efficiency, time, as well as beryllium content. Use of a stronger Sb^{124} source will increase the counting rate, but there is a practical limit to source strength for safety reasons. Geometry of exposure can be improved in a laboratory instrument but not in a portable instrument. Some increase in detector efficiency is achieved by using a boron trifluoride Geiger tube. The easiest way to improve count accumulation is to increase the time for each determination.

Inasmuch as progressively longer counting periods are necessary to provide statistically valid counts as grade of sample decreases, the time requirement for high accuracy on low-grade samples may be impractical. Moreover, it may be impossible to standardize test conditions in the field to obtain high accuracy in testing regardless of grade level. Test procedures must be adjusted with the required and/or attainable degree of accuracy in mind.

Operating Procedures for Beryllium Detectors

Owing to the natural decline in Sb^{124} radiation level, daily instrument calibration is mandatory, both in the laboratory and the field. Cosmic background varies and must be redetermined at intervals.

Laboratory operating procedures for nuclear beryllium detectors are essentially the same as the standard routines applicable to radiation measurement instruments.

The portable instrument is used in two ways in the field. Sometimes rock outcrops, overburden, or dumps are scanned directly by placing the instrument on the material to be tested at predetermined intervals or at points chosen because of visible signs of mineralization. At other times, particularly when starting work in a new area, rock specimens and sacked samples of bedrock material, overburden, and dumps are brought to the instrument at a central location.

Variable conditions in sample exposure, and consequently in accuracy of determinations, are inevitable in fieldwork owing to the usually erratic distribution of beryllium minerals in nonuniform outcrops and other sampled material. For these reasons field evaluations are never precise.

Mineralization can be overlooked when the beryllium is contained in discrete minerals that are sparsely distributed in exposed rock surfaces. However, mineralization of commercial or near-commercial grade is not likely to be overlooked. In the Bureau of Mines investigations, material that gave even slight evidence of beryllium minerlization, either by appearance or by the detector, was submitted to the laboratory.

Radiation Safety

Operating routines in nuclear beryllium detection must be set up in accordance with safety requirements. However, safe conditions are not difficult to maintain if common sense precautions are taken. In the laboratory, lead bricks can provide extra shielding around the instrument if monitoring of facilities indicates that other protection, in addition to the shielding built into the instruments, is necessary. Access to laboratories should be restricted. Vehicles transporting instruments must be posted with radiation caution signs, and unattended vehicles must be locked. Field personnel must respect the hazard presented by the source, which is partially exposed when in

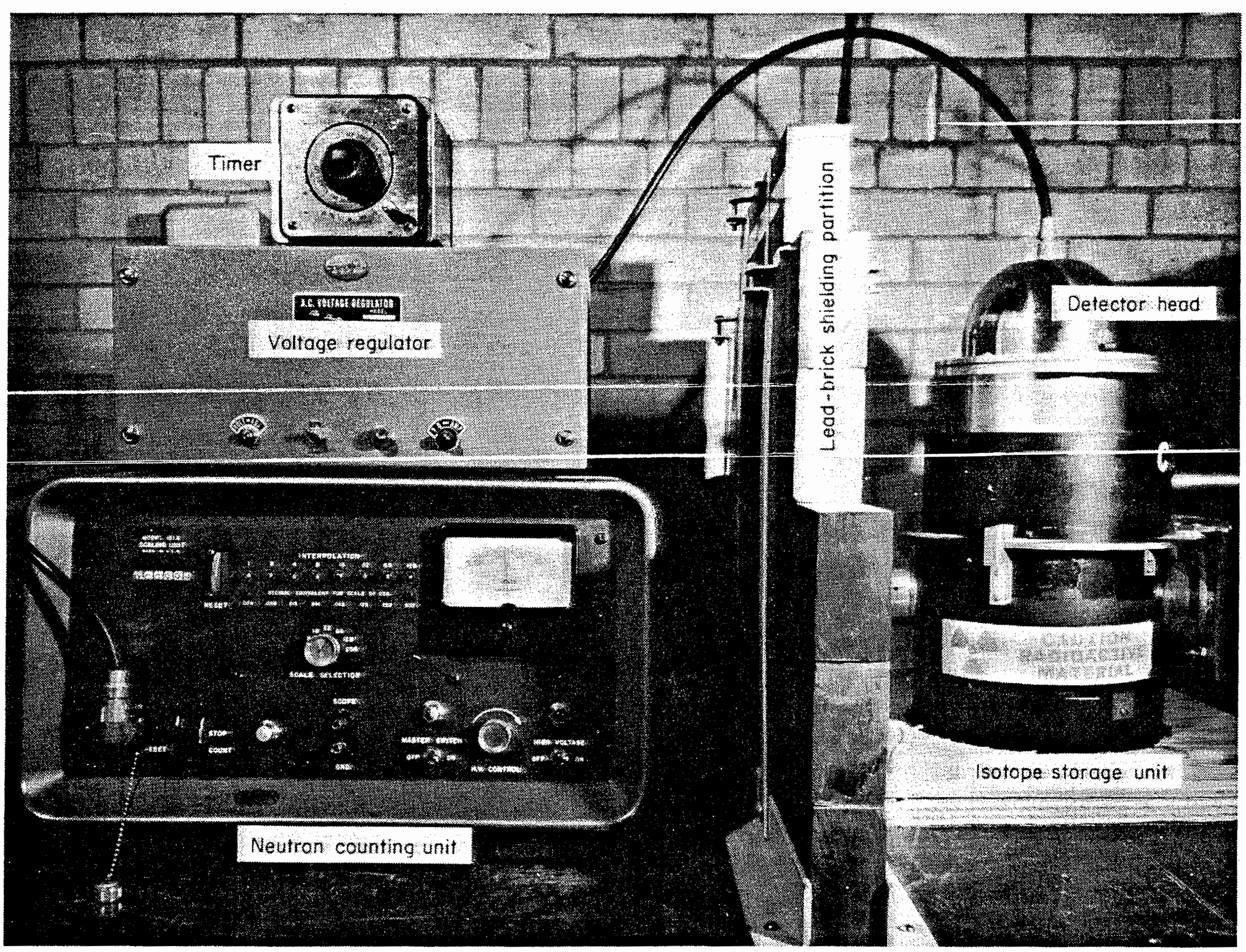

FIGURE 2. - Laboratory Beryllium Detector

actual use. Personnel, in both laboratory and field, should wear film badges and/or dosimeters to monitor exposure to ionizing radiation.

Equipment Used by Bureau of Mines

A nuclear beryllium-detecting instrument, designed by scientists of the Federal Geological Survey (39), was acquired in March 1960, and used for laboratory work in the Bureau of Mines Mineral Resource Office, Denver, Colo. (fig. 2). A commercially built portable instrument for field use was obtained in April 1960, and a second portable unit in October 1961.

The laboratory instrument used a 100-mc Sb^{124} gamma source and a scintillation-type detector with photomultiplier-tube amplifier, as did one of the portable instruments with, however, an 80-mc source. The other portable instrument used two boron trifluoride Geiger tubes as a detector-amplifier and a 50-mc source.

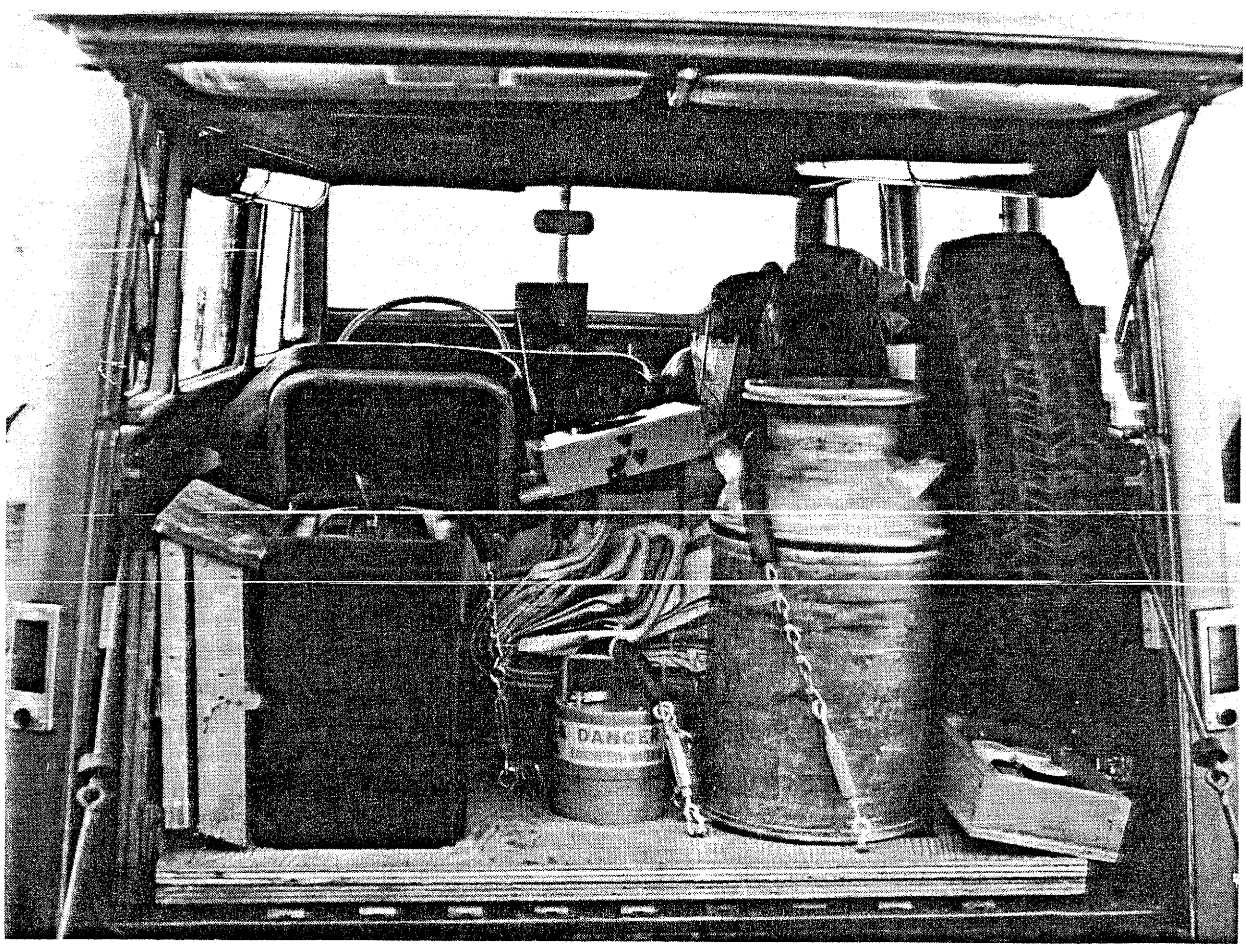

FIGURE 3. - Arrangement of Beryllium Detector and Other Equipment in a Four-Wheel-Drive Vehicle.

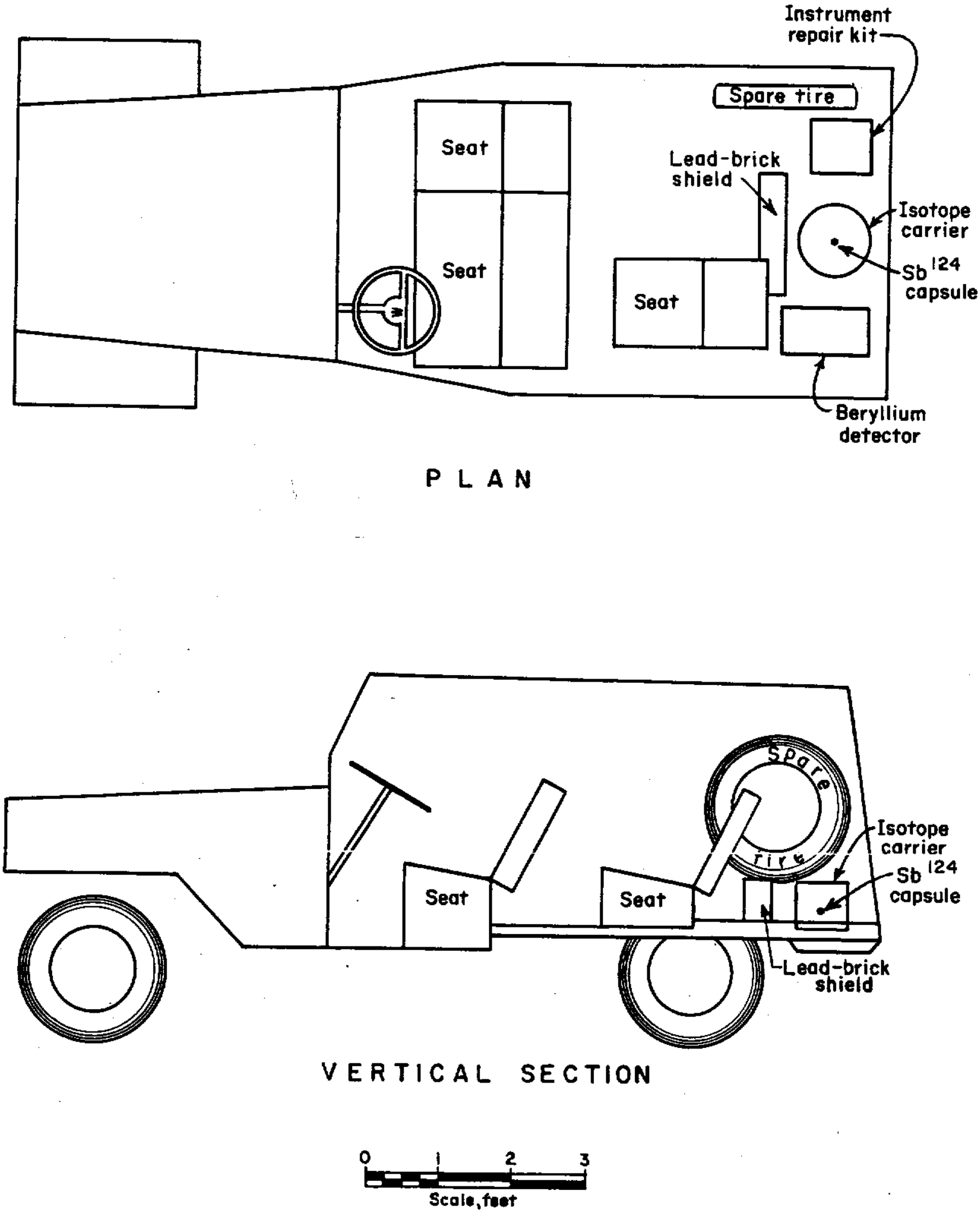

FIGURE 4. - Sketch Showing Placing of Beryllium Detection Equipment for Transporation in a Four-Wheel-Drive Vehicle.

A four-wheel-drive station wagon (figs. 3, 4) was used to transport personnel, a portable detection instrument, a leadlined carrier for storing the radioisotope (Sb^{124}) used in the detecting reaction, and other accessory equipment. The vehicle also served as a storage facility, thus meeting radiation safety standards for protecting the public during stops in towns and travel over public thoroughfares. The rear compartment of the vehicle was fitted with a pallet consisting of two layers of 3/4-inch plywood bolted together. Cutouts in the top piece of plywood, shaped to receive the bases of the major pieces of equipment, formed recesses in which equipment items were secured by lashing with light chains attached to eyebolts in the pallet and tightened by turnbuckles. Cutouts were provided for a detection instrument, for a toolkit, for the isotope carrier, and for six standard 2- by 4- by 8-inch lead blocks placed immediately behind the rear seat. This additional shielding gave increased protection to personnel during travel by further reducing the low level of ionizing gamma radiation that escaped the isotope carrier.

Samples, other field equipment, and supplies were stowed within the vehicle or secured to a rack on the roof. A section of 4-inch stovepipe was mounted under the roof at the right side to hold the dismantled carrying pole and one on the left side for large maps. Auxiliary air springs were installed on the rear axle of the vehicle to support the weight of equipment, including the 150 pounds of additional lead shielding and the maximum sample load gathered during each field trip.

During actual field operation, the detector had to be transported so as to avoid exposing personnel to radiation from the source, which cannot be completely shielded in a field instrument. Two men were necessary. Several models of light steel-tubing frames were improvised for carriers, to which an instrument was secured at a distance of at least 3 feet from the men stationed at either end of the carrier. The light frames were too limber, and heavier tubing added too much weight for a continuing operation. Eventually, a single two-piece pole with the instruments secured at the center point proved to be the most feasible carrying arrangement. Two types were used (figs. 1, 5).

NONPEGMATITIC BERYLLIUM MINERALS

Some beryllium-bearing minerals known to be present in nonpegmatitic rocks are listed in table 1.

Although beryl has been the sole commercial source of beryllium historically, bertrandite, phenacite, helvite, and eudidymite are potential source minerals that may assume economic importance.

NEW USES AND PRODUCTION OF BERYLLIUM

Some outstanding new uses of beryllium have been developed for the space program. A beryllium heat shield was used on Friendship 7; beryllium shingles on Aurora 7; and beryllium antennae on Sigma 7, Telestar series, Lofti, and Traac. Designs developed in the Gemini program and Saturn rockets included the use of beryllium. Recent research suggests beryllium as a fuel for interspace vehicles and use of beryllium-aluminum alloy as structural components in aircraft and space vehicles.

TABLE 1. - Partial list of beryllium-bearing minerals identified in analyses of nonpegmatitic rocks[1]

Mineral	Chemical composition	BeO, percent
Bertrandite....................	$Be_4Si_2O_7(OH)_2$................	39.6-42.6
Beryl..........................	$Be_3Al_2(SiO_3)_6$.................	10.0-14.0
Bromellite.....................	BeO.............................	100.0
Chrysoberyl....................	$BeAl_2O_4$......................	16.9-19.7
Danalite.......................	$Fe_4Be_3Si_3O_{12}.S$................	12.7-13.8
Euclase........................	$BeAlSiO_4(OH)$.................	16.9
Eudidymite.....................	$HNaBeSi_3O_8$...................	10.6-11.1
Helvite........................	$Mn_4Be_3Si_3O_{12}.S$................	10.5-15.0
Phenacite......................	Be_2SiO_4......................	44.0-45.6
Swedenborgite..................	$NaBe_4SbO_7$....................	35.3
Trimerite......................	$Be_3Mn_2Ca(SiO_4)_3$...............	17.1
Allanite.......................	$(Ca,Ce)_2O.Fe_2OH.Al.(Al,Si_3)O_9$..	[2]5.5
Clinohumite....................	$Mg_7[Mg(F,OH)]_2$................	[2]1.7
Garnet.........................	$Ca_3(Al,Fe)_2Si_3O_{12}$.............	[2].2
Idocrase (vesuvianite).........	$Ca_{19}(Al,Mg)_{13}Si_{18}(O,OH,F)_{76}$....	[2]4.0
Zircon.........................	$ZrSiO_4$.......................	[2] [3]14.0

[1]Source: (40, pp. 10-15).
[2]Beryllium is an impurity when present in these minerals.
[3]Beryllium variety (alvite) very rare.

Table 2 shows the salient statistics of beryllium in the period 1960-63. The 1960-62 domestic production of low-grade ore came largely from the Boomer and Redskin deposits, Park County, Colo.

TABLE 2. - Salient statistics of beryllium, 1960-63[1]

Year	Domestic ore				Imported ore		U.S. consumption short tons[2]
	Cobbed beryl		Low-grade ore				
	Short tons[2]	Price per unit BeO	Short tons[3]	Price per unit BeO	Short tons[2]	Price per unit BeO	
1960.........	244	$45	265	$31	8,943	$29	9,692
1961.........	317	(4)	805	(4)	8,516	30	9,392
1962.........	218	(4)	760	(4)	8,552	31	7,758
1963.........	1	(4)	750	(4)	6,243	24	7,934

[1]Bureau of Mines Minerals Yearbooks, 1960-63.
[2]Cobbed beryl containing approximately 11 percent beryllium oxide (BeO).
[3]Ore contained an estimated 3.1 percent BeO.
[4]Figure withheld to avoid disclosing individual company confidential data.

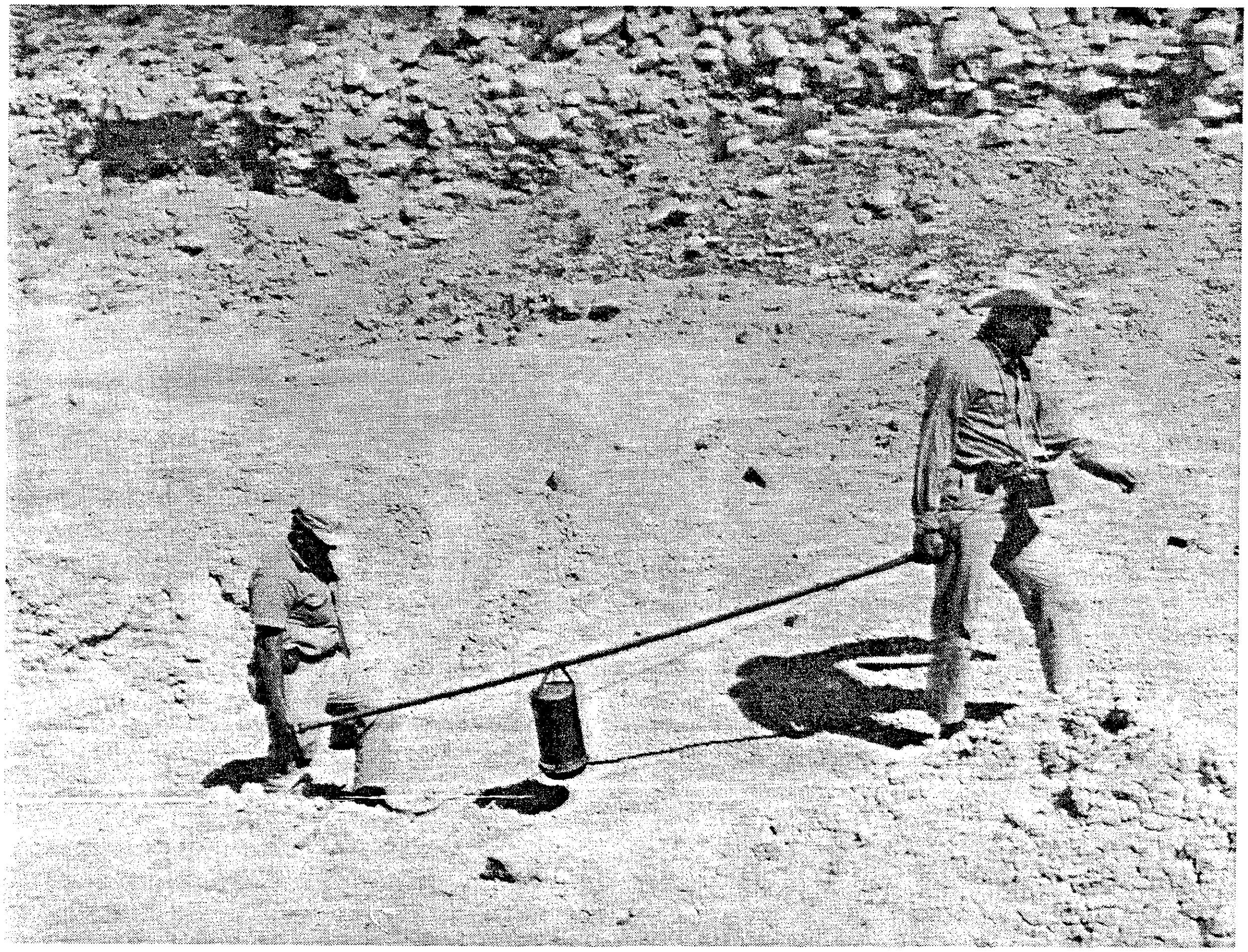

FIGURE 5. - Method of Carrying a Portable Beryllium Detector, Spor Mountain Area, Juab County, Utah.

WORK BY THE BUREAU OF MINES

A total of 155 properties were examined, during which over 5,500 samples were tested for beryllium content by nuclear detection methods. Of these, nearly 3,500 required further checking by laboratory analysis. Fieldwork consisted of examining outcrops and mine workings to establish structural relationships and rock types. Rock exposures and mine dumps were scanned with a portable detector and, when readings exceeded background, chipped samples were taken for checking. Sometimes it was necessary to run Brunton surveys to establish the structural relationship of separate rock exposures when mine maps were not available.

Ore deposits in the Badger Flats area near Lake George, Park County, Colo., were studied quite intensely as these deposits were the first commercial source of nonpegmatitic beryllium ore. Sampling and investigating the outcrops and mine workings in the Badger Flats area were undertaken to learn more about the extent of the ore bodies and establish criteria on beryllium enrichment that might be useful in studying these deposits and similar deposits elsewhere.

BUREAU OF MINES BENEFICIATION STUDIES

The Bureau has done extensive research on beneficiating nonpegmatitic beryllium ores from Iron Mountain, N. Mex. (26); Lake George area, Colo. (23); and Spor Mountain, Utah (13-14, 17-18, 32). Generally most of the contained beryllium can be recovered from these low-grade ores by flotation, solvent extraction, and acid leaching or by a combination of these methods, but costs might be too high to compete commercially with imported beryl.

SIGNIFICANT OCCURRENCES

The 155 properties examined are listed by State and county in appendix A. Of these, 24 are considered to have significant amounts of material that contain more than 0.10 percent BeO and possibly several could be exploited economically with a moderate increase in demand, especially under national emergency conditions.

Arizona

All properties examined in Arizona for beryllium are shown on figure 6.

Beryl Hill Prospect

The Beryl Hill claim (fig. 6, loc. 2) is one of seven claims located on the eastern slope of the Dos Cabezas Mountains, a north-trending range that rises abruptly out of the desert 7.4 miles south of Bowie and three-fourths of a mile west of the Apache Pass Road. The mineralized exposures, at an altitude of 4,800 feet, are on the steep western slope of a ridge 800 feet above the desert floor. This area could not be reached by four-wheel-drive vehicle.

The property covers an outcrop of Precambrian biotite gneiss (4) enclosed by porphyritic granite. An opencut 22 feet long, 4 feet wide, and 12 feet deep in gneiss exposed two intersecting granitic dikes. The larger dike, 3 feet wide, strikes S 23° E and dips almost vertically. The cross dike, 11 inches wide, strikes S 8° W and dips 55° W, roughly parallel to the foliation of the gneiss. The granitic filling of the vertical dike contains a 3- to 8-inch beryl-bearing quartz core. Small beryl crystals, present wherever core contacted the enclosing granitic dike material, are elongated in the plane of the contacts. Beryl crystals also occur along contacts of dikes with gneissic wall rock, oriented perpendicular to the plane of these contacts. Very little beryl was observed in the larger dike away from the contacts or in the core. The gneiss had no detectable beryl. Sparse beryl is present as a filling in minute fractures in the cross dike. Another vertical dike outcrop, in line with the vertical dike in the opencut as projected, is exposed by a trench 17 feet long, 4 feet wide, and 2 feet deep. This dike is 45 feet southwest of the opencut and contains no quartz core or visible beryl, but scanning with a portable beryllium detector indicated the presence of some beryllium. Cobbed specimens revealed a thin, pale-blue coating along

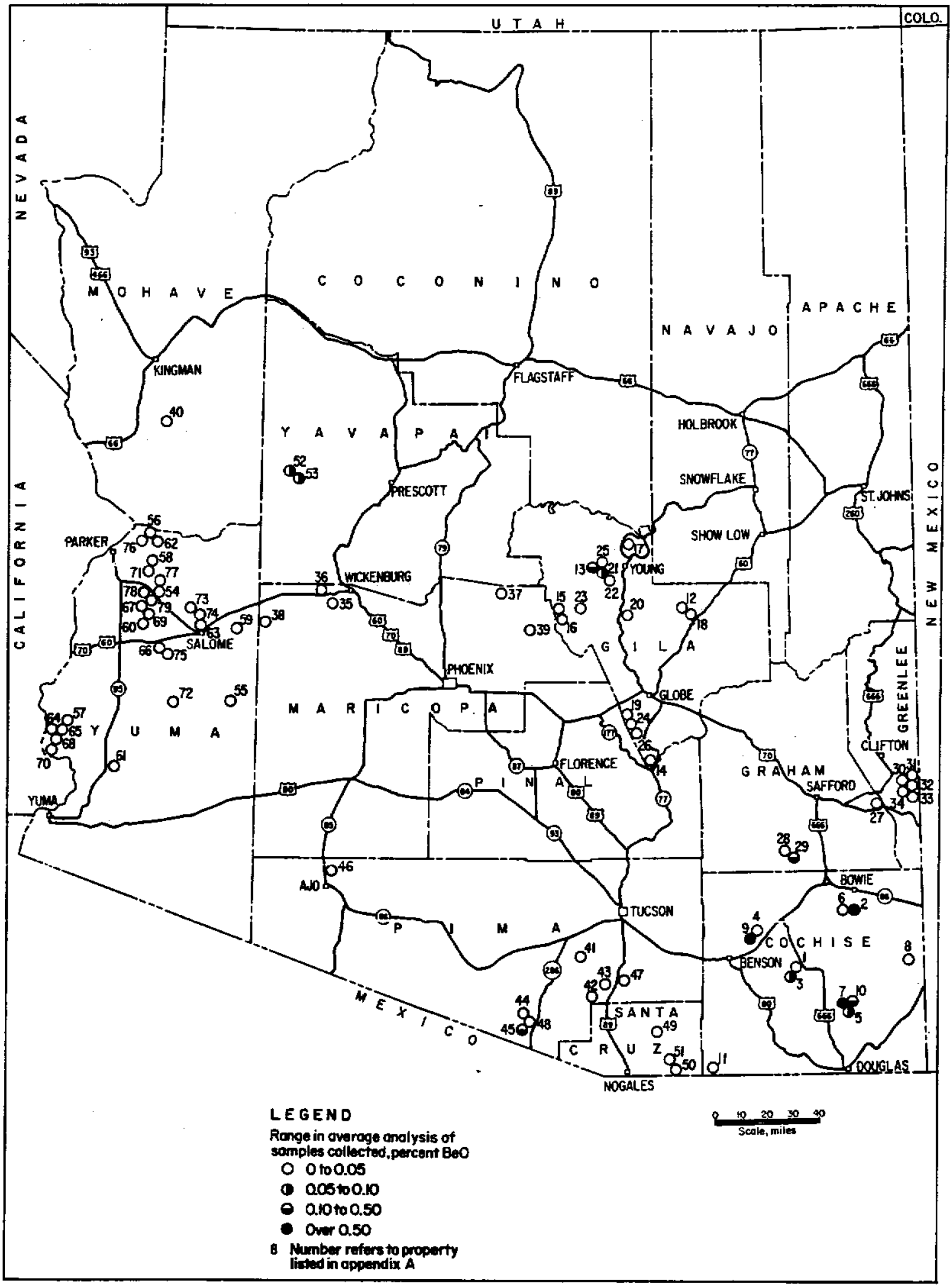

FIGURE 6. - Location of Properties Examined for Beryllium in Arizona.

fractures; the coating identified as fine-grain beryl after testing with the portable beryllium detector.

Seven selected samples from representative exposures were found to contain 0.18 to 2.63 percent BeO (equivalent) when tested with the laboratory beryllium detector.

Tungsten King Mine

The Tungsten King mine (fig. 6, loc. 9) contains small tungsten-bearing quartz veins. This prospect consists of a group of 12 claims which are located approximately halfway up the western slope of the Little Dragoon Mountains, about 16 miles northeast of Benson.

Quartz veins containing sparse beryl, scheelite, and sulfide minerals are generally parallel to an irregular, generally steep-dipping, contact between Precambrian schist and Tertiary granite (4). The quartz veins, ranging from 1 inch to 6 feet in width, occur either at the contact or in the schist within 35 feet of the contact.

The property has been developed by two adits: one inaccessible 275-foot adit with crosscuts, and one 25-foot adit along the granite-schist contact. There are also numerous opencuts and trenches in the contact zone.

Many specimens of beryl from outcrops of quartz stringers and representative samples of granite and schist were collected along 2,000 feet of the granite and schist contact. The samples were tested on the site with a portable beryllium detector. Granite and schist gave negative results. Only vein matter containing visible beryl gave a positive test. The beryllium appears to accompany the tungsten enrichment, occurring sparsely in the quartz veins within 10 to 15 feet of the contact. Veins further away apparently do not contain either beryllium or tungsten in appreciable amounts.

While the reserve potential of this occurrence is very low, a description is included because the beryl accompanies tungsten mineralization that in itself is economically marginal. The beryl and tungsten together might constitute a minable resource during a national emergency.

Breadpan Beryllium Deposits

The Breadpan beryllium claims (fig. 6, loc. 13) are in Breadpan Canyon, on the northeast slope of the Sierra Ancha Mountains (figs. 7 and 8), 13 miles westerly from Young. The last 2 miles of the unimproved access road descends in a steep switchback and ends at the Flying W Ranch on the floor of Spring Creek Canyon. From here, the claims can be reached by Jeep[3] trail in the bed of Breadpan Creek above its junction with Spring Creek.

[3]Use of the trade name "Jeep" is necessary for clarity and does not imply endorsement by the Bureau of Mines.

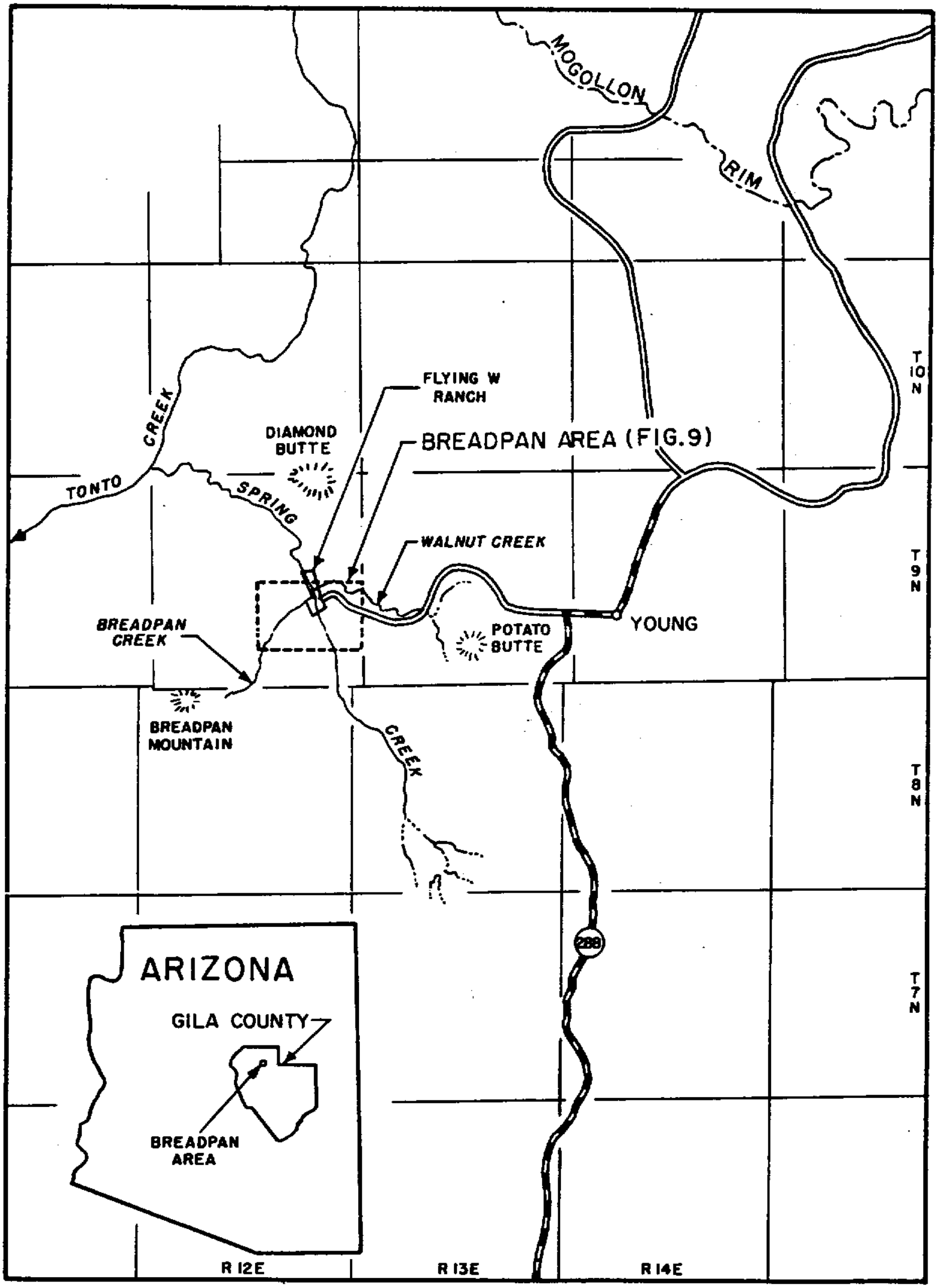

FIGURE 7. - Location of Breadpan Area, Gila County, Ariz.

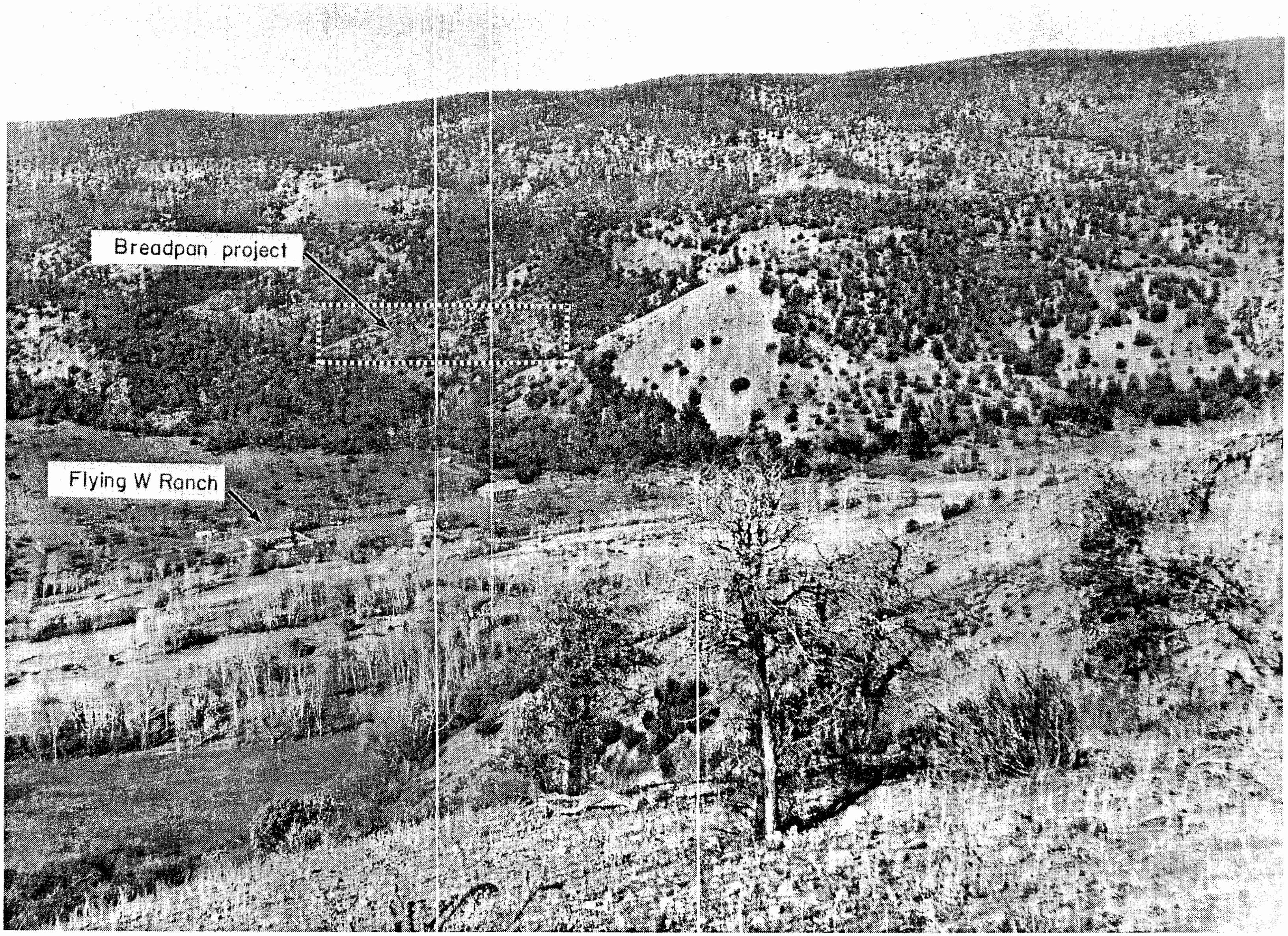

FIGURE 8. - View of Breadpan Project Area, Gila County, Ariz.

The known beryllium-bearing rock, which is a schist member of the Precambrian Alder Formation (5, 21), crops out on the steep northwest slope of Breadpan Canyon from creek level to a quartzite ledge 400 to 500 feet above the canyon floor. The Alder formation continues above the quartzite but no beryllium was detected. The location of Alder Formation outcrops with respect to property lines and surface features is shown on figure 9.

The schist, where exposed in Breadpan Canyon (fig. 10), trends N 60° E and dips about 70° NW, as does the Alder Formation. The outcrop, paralleling the creek, has a strike length of about 1.5 miles and an exposed width of 400 feet.

A normal fault, approximately parallel to the strike of the Alder Formation, coincides with the line of that portion of Breadpan Creek near the Bread Pan claims. On the northwest side of the canyon, the Alder Formation is in a downthrown fault block in relation to the basic volcanics forming the southeast canyon slope. The Breadpan fault is one of several regional faults which, together with lesser faults, result in complicated structural relationships in the area. Faulted blocks of the Alder Formation also crop out at other points in the general area. The beryllium-bearing schist member is present on the northeast side of Spring Creek Canyon, farther northeast on Walnut Creek, and elsewhere. Brief reconnaissance of these areas indicated slight beryllium enrichment. These additional areas would warrant further work if the beryllium deposits along Breadpan Creek become economically important.

The schist along Breadpan Creek consists largely of dark-colored rock containing light-colored stringers of feldspar, a few inches thick, in bands or zones up to several feet wide (fig. 11). These bands are concordant to the foliation of the schist and with the general trend of the Alder Formation. The feldspar bands vary in width along their trend and are sparsely distributed throughout the schist member, constituting possibly between 5 and 10 percent of the total volume of the schist. A specific stringer of feldspar may not maintain its identity for more than a few feet, but stringers in a braided structure tend to persist in zones that can be traced 200 to 300 feet. Further investigation probably would demonstrate greater horizontal continuity. Persistence of the bands at depth has not been established but presumedly will be similar to their horizontal continuity.

Associated with many feldspar stringers are fine, discontinuous quartz veinlets in networks that occasionally form quartz-rich zones up to 2 feet wide. Sparse beryllium enrichment occurs with the quartz veinlets in the form of blebs of blue beryl up to 1/4-inch in diameter and as paper-thin, discontinuous fracture fillings. Small specks of blue beryl usually can be discerned by close inspection of samples containing 0.1 percent or more BeO. Accessory fluorspar, tourmaline, garnet, magnetite, and limonite have been identified in veinlet samples. Tests made at a private laboratory indicated some bertrandite, but this beryllium mineral was not identified in Bureau of Mines work.

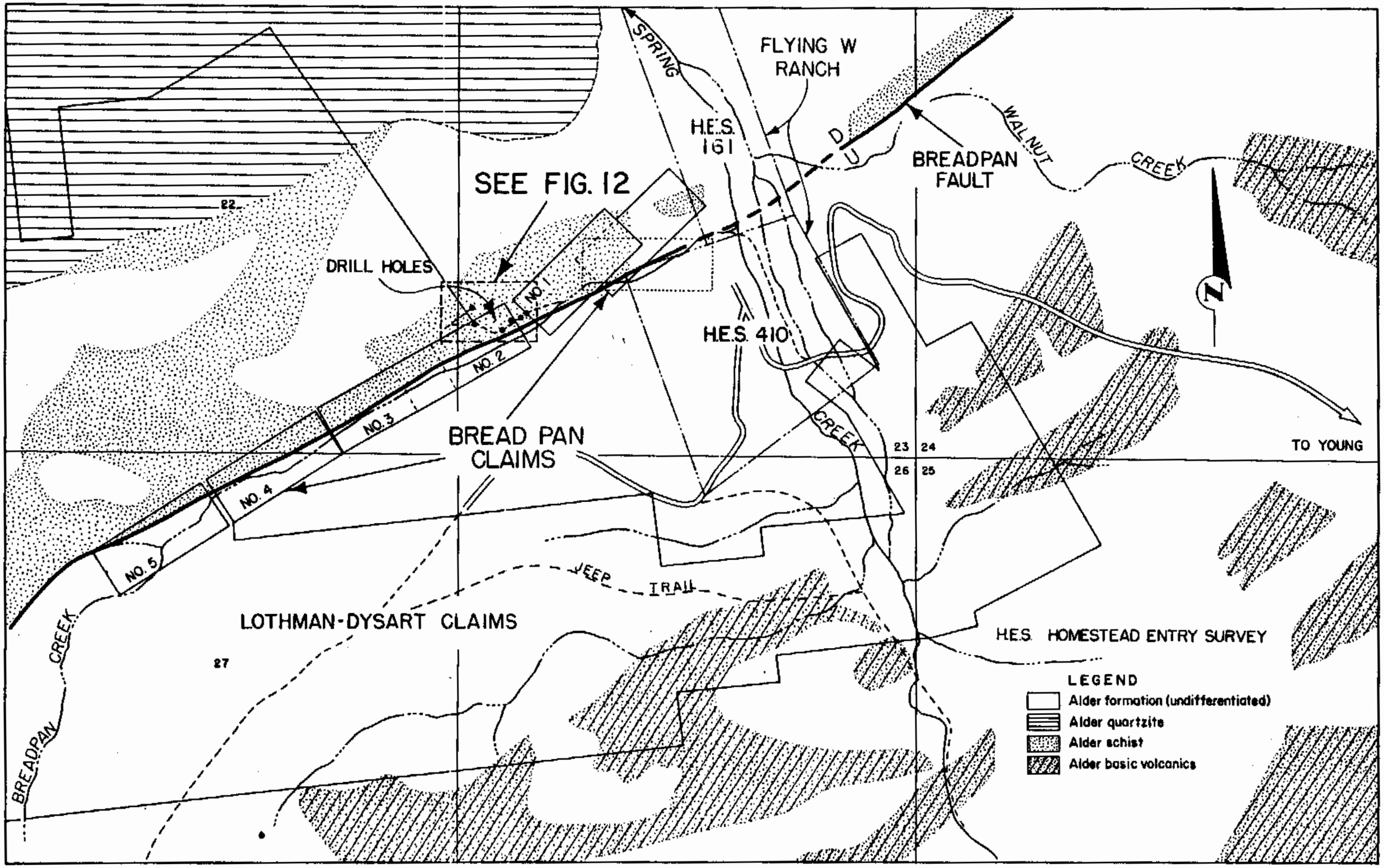

FIGURE 9. - Map of Breadpan Beryllium Area Showing Bread Pan Claims and Alder Formation Outcrops, T 9 N, R 12 E, Gila County, Ariz. (Adapted from Older Precambrian Rocks of the Diamond Butte Quadrangle, Gila County, Ariz., R. G. Gastil, 1958).

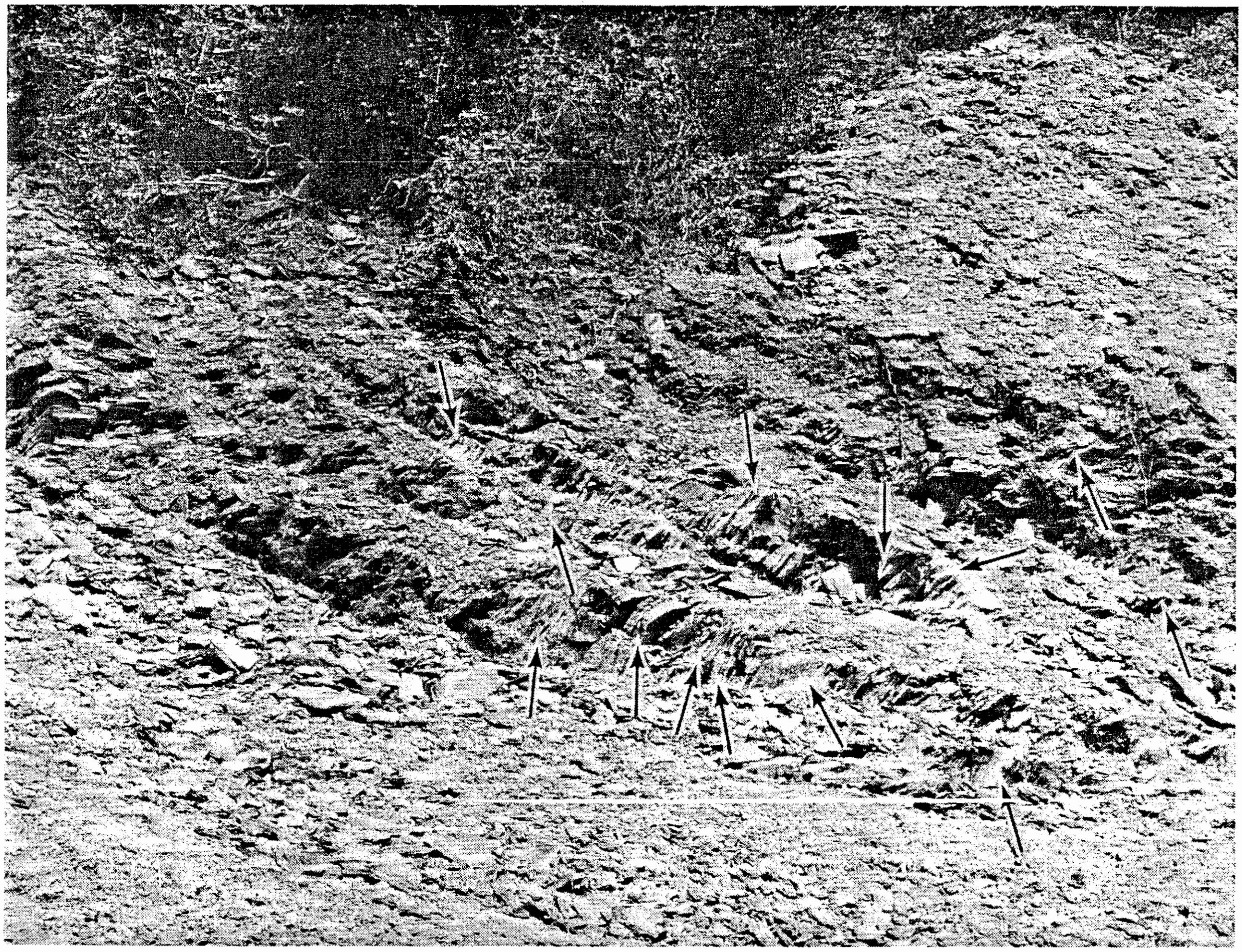

FIGURE 10. - Outcrop of Beryllium-Bearing Stringers in Alder Schist Formation in Stripped Area of the Breadpan Area, Gila County, Ariz.

The veinlets generally appear concordant with the schistosity; however, in the prospect pit at the site of drill hole 1 (fig. 12), a beryllium-bearing quartz stringer from a fraction of an inch to 16 inches wide had a strike of N 12° W and dip of 74° NE, crossing the schistosity at an oblique angle. This discordant attitude suggests that beryllium deposition might be associated with a cross-fracture system.

Except for scattered pits excavated primarily as claim discoveries, exploration was confined to an area of about 1,000 by 400 feet on the north slope of Breadpan Canyon within the limits of Bread Pan 1 and 2 claims (figs. 9 and 12).

During exploration by a private company from November 1961 through January 1962, six holes were drilled to depths of 62 to 156 feet, using a truck-mounted rotary rig and 4-3/4- or 5-3/4-inch bits.

FIGURE 11. - Feldspar Stringer in Schist, Bread Pan 2 Claim, Gila County, Ariz.

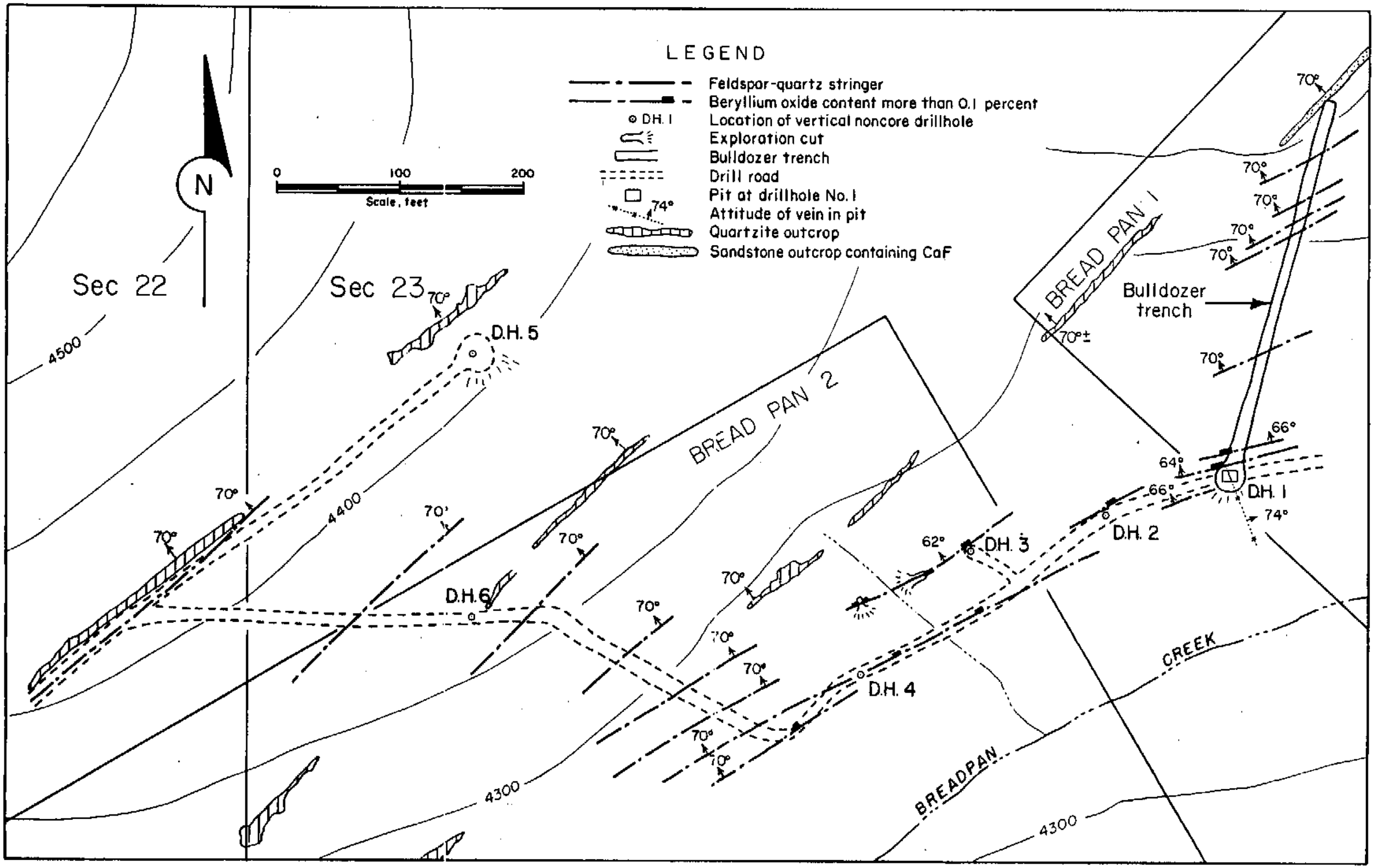

FIGURE 12. - Exploration Sites, Bread Pan Claims 1 and 2, Sec 23, T 9 N, R 12 E, Gila County, Ariz.

Holes were drilled at locations shown on figures 9 and 12. The water table was encountered in drill hole 1 at 114 feet and in drill hole 2 at 83 feet. Beryllium minerals of slight significance were found in drill cuttings from the intervals 12-16, 18-20, 28-30, 60-62, and 66-70 feet in drill hole 1. A low order of beryllium enrichment was evident in most of the drill holes (appendix B).

After drilling was completed, a 467-foot bulldozer trench was excavated in the schist member exposing seven narrow feldspar bands (fig. 12). Results of scanning trench exposures with a portable beryllium detector indicated slight enrichment in the feldspar bands and virtually none in the schist. No beryl was visible, and laboratory tests on seven samples gave essentially negative results.

A pit was excavated to a depth of about 15 feet below the original road grade at the site of drill hole 1 to investigate the source of the beryllium-bearing cuttings obtained in the 12-16-foot interval. A stringer ranging in width from a fraction of an inch to 16 inches and containing 0.55 percent BeO was exposed; the best beryllium showing found on the property. An interesting mineral occurrence was a 2-inch-wide streak of chalcocite exposed in the floor of the pit. So far as known, it has no particular significance in relation to beryllium.

A reconnaissance survey using the beryllium detector was made over the large number of Bread Pan claims. Outcrops and rock exposures in many of the discovery pits were scanned with the detector, and samples collected by the lessees from other pits were tested; little or no beryllium was indicated.

An outcrop of the schist member of the Alder Formation on the east side of Spring Creek Canyon in the NE¼ of section 26 indicated slight evidence of beryllium in feldspar bands exposed along the creek; however, no point of enrichment was found. In section 24 (fig. 7), on Walnut Creek, a tributary of Spring Creek, another outcrop, presumably the same schist member, gave an appreciable count with the portable detector.

A total of 38 samples were collected for laboratory testing at points where scanning indicated possible beryllium occurrences. Of the 38 samples selected because of anomalous count in the field, 5 gave laboratory analyses of 0.19, 0.15, 0.14, 0.12, and 0.087 percent BeO, and the balance 0.01 percent BeO or less. The samples with significant beryllium content were taken at isolated spots and did not represent any areas of continuous beryllium enrichment.

Descriptions and analyses of all samples collected are given in the appendixes. Appendix B lists the samples of drill cuttings. Appendix C lists the samples taken on Bread Pan 1 claim in the crosscutting trench and in the pit excavated around drill hole 1.

Because of the relation of the vertical drill holes to the 70° dip of the formation, not more than 50 feet of formation, measured normal to the foliation planes, was crosscut in any hole; the actual formation thickness represented in a 2-foot sampling interval was 8 inches.

During the private project on the Bread Pan claims, a sample was sent to a research laboratory for mineralogical analysis and preliminary metallurgical testing. This sample of cuttings, taken from the interval 12-16 feet in drill hole 1, contained 0.295 percent BeO by activation analysis, according to the laboratory. A Bureau of Mines analysis for the same interval was 0.21 percent BeO. This compares with the 0.55 percent BeO content in the 16-inch veinlet found later in the pit excavated at drill hole 1. None of these samples represent a minable ore width.

The laboratory report concluded that: "If the sample was representative of the ore available, concentration by flotation was feasible, although a heavy coating of limonite noticed on the beryllium minerals present--beryl and bertrandite--was a significant problem."

Colorado

Locations of the 22 Colorado properties examined are shown in figure 13.

Mount Antero Area

Mount Antero, in the Sawatch Range, Chaffee County, has long been known for its occurrences of gem quality beryl and, more recently, for possible commercial deposits of beryllium (fig. 13, locs. 3, 4, 5). The exposed beryllium-bearing structures are largely above timberline on the precipitous upper slopes of Mount Antero (fig. 14) and nearby Mount White. Beryllium minerals are widely but sporadically distributed in the Mount Antero granite and associated intrusives in enough abundance to be a possibly significant large-tonnage reserve of low-grade ore. The only occurrences of beryllium developed at present would require uneconomical selective mining and sorting to make a product approaching imported beryl.

The geology of the Mount Antero deposits has been described by Adams (1). The area was visited by Bureau of Mines personnel in 1958 and again in 1959.

CYAC Group

The CYAC group consists of 73 contiguous claims (fig. 13, loc. 3, fig. 14) on the upper slopes of Mount Antero. The Mount Antero access road leads directly to this property.

Beryl crystals, as much as 2 inches in diameter, phenacite, and bertrandite occur in disseminated pods in fractured, hydrothermally altered Mount Antero Granite (1). These pods range in size from 1/4-inch blebs to irregularly shaped masses up to 4 feet in diameter. Minor amounts of fluorite, limonite, and malachite are present also. Beryl blebs as much as 6 inches in diameter, with subordinate bertrandite, appear both in granite float and in what appears to be solid bedrock. Beryl also occurs erratically in iron-manganese-oxide-stained pyrite-quartz veins more than 300 feet long and up to 3 feet thick; beryl and bertrandite occur in veinlets that are less than 50 feet long and 2 inches thick. Crystals of beryl, including the variety aquamarine, phenacite, quartz, feldspar, and fluorite, also occur in partially

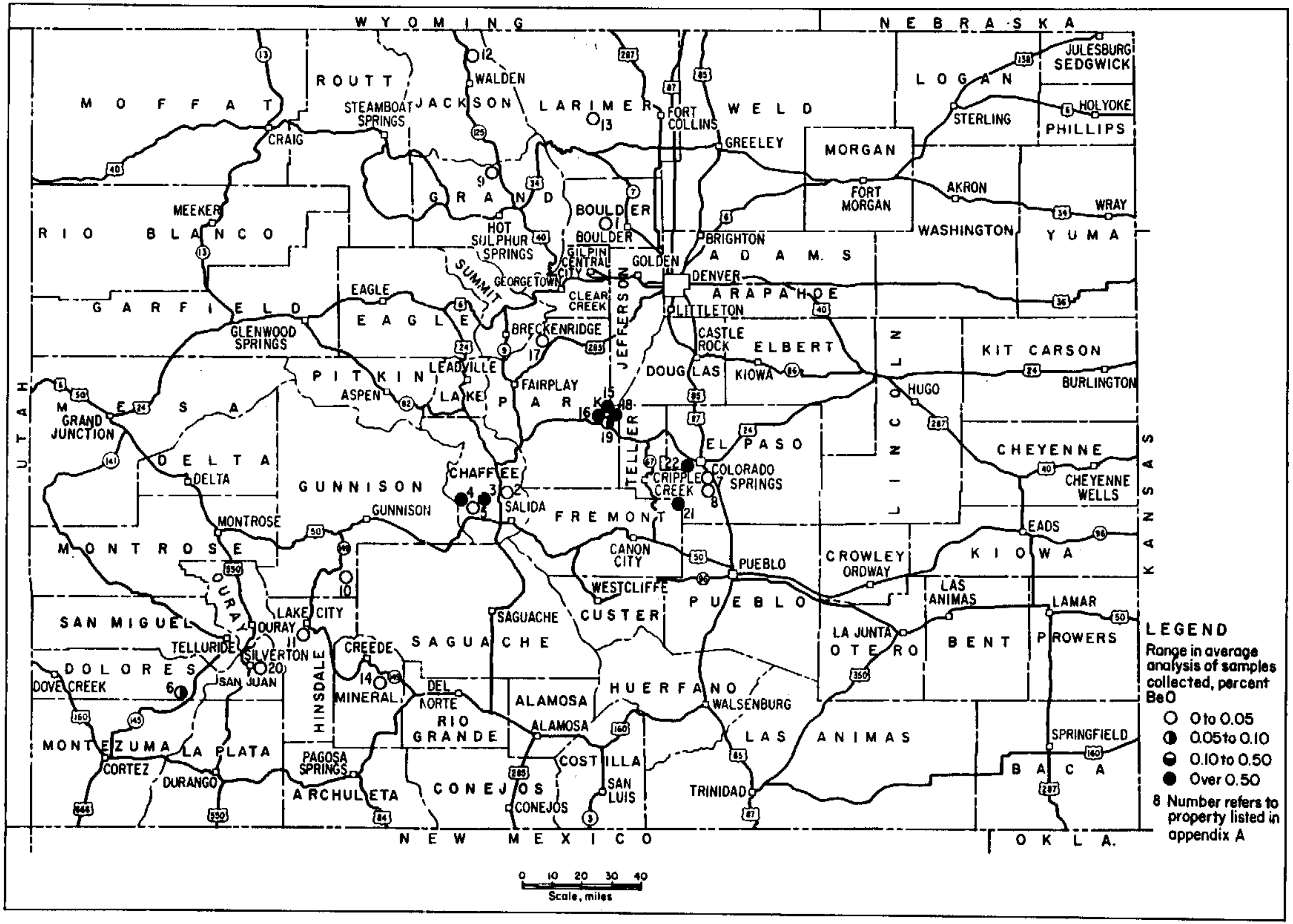

FIGURE 13. - Location of Properties Examined for Beryllium in Colorado.

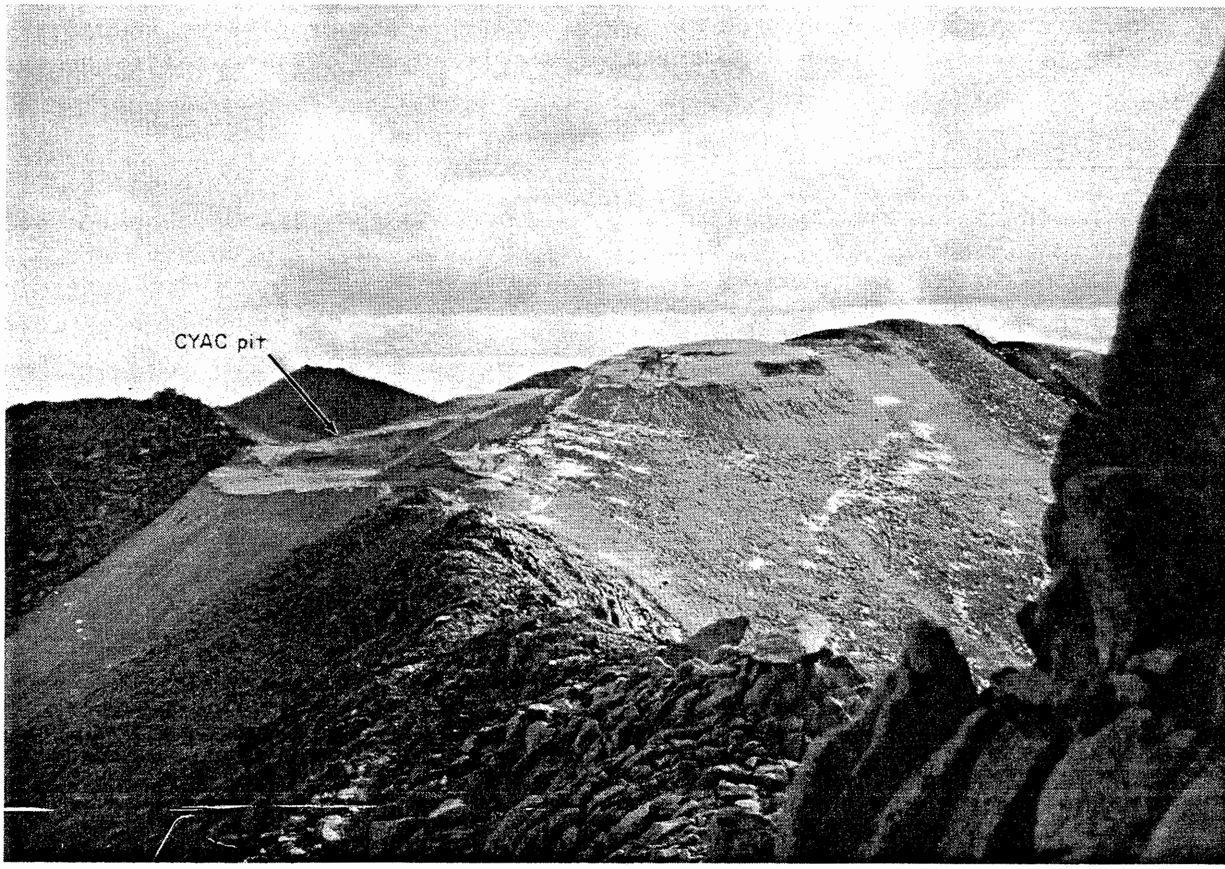

FIGURE 14. - CYAC Pit on Ridge Near Crest of Mount Antero, Chaffee County, Colo.

filled miarolitic cavities in granite. Scattered crystals of blue to green beryl occur along the wall zones of two small, poorly exposed pegmatites also containing quartz, feldspar, and muscovite as the chief minerals and fluorite as a minor constituent.

The property is developed by one main open pit, several small pits, and about a dozen open trenches extending southwest from the main pit.

Atlas Group

The Atlas group (fig. 13, loc. 4) comprises 15 claims in sec 19, T 51 N, R 7 E, Chaffee County, approximately 14 miles northwest of Salida. A Jeep trail extends southerly from the CYAC claims on Mount Antero to this property on the north side of Mount White.

Beryl, aquamarine, and phenacite occur as crystals in vugs, miarolitic cavities, and as blebs in granite. Beryl and bertrandite accompany quartz in banded quartz-orthoclase rock in short, narrow, quartz veinlets less than 50 feet long and less than 2 inches wide.

Exploration consisted of several small prospect pits scattered throughout the property. Present exposures of beryllium are few and scattered over a length of 2,300 feet.

California Mine

The California property (fig. 13, loc. 5) consists of three patented claims in sec 27, T 51 N, R 6 E, Chaffee County. The property, at an elevation of 12,500 feet, overlooks a saddle at the base of a ridge extending 2.3 miles southwesterly from Mount Antero. The mine may be reached by a Jeep trail from the CYAC claims.

The California mine was explored in 1917 for molybdenum. Workings of that period comprised a 50-foot inclined shaft, a 90-foot crosscut adit, and 350 feet of drifts. Small lots of cobbed molybdenum ore were shipped for metallurgical testing, but no subsequent production was reported. According to Worchester (43), the 1.5- to 3-foot California vein in quartz monzonite was developed for a strike length of 500 feet in the adit workings and to a depth of 50 feet in the shaft. The vein trends N55°-75° E and dips between 80° NW and vertical.

The adit workings were inaccessible at the time of both Bureau of Mines visits to the Mount Antero area. Mineralogical specimens of vein matter collected from the dump contained quartz, beryl, molybdenite, ferromolybdates, muscovite, and tourmaline. Minor amounts of magnetite, fluorite, rutile, and brannerite have been reported (1). The beryl occurs as small, green, hexagonal crystals up to one-fourth inch in diameter and 2 inches in length.

Bureau investigation indicated a beryllium potential for the California vein, but resulted in no specific data on which to base a reserve estimate.

In 1960, an examination of the California property was made by a private operator who reopened the adit workings. On the basis of examination of vein exposures in the workings, along outcrops, and four samples of 1.5-foot-wide vein matter taken in drift floors, an estimate of about 2,200 tons of indicated and inferred ore and a potential of about 17,000 tons more was made by the operator in a block about 750 feet long, extending in depth 265 feet below the tunnel level. The estimated grade in this reserve was 1 percent BeO.

Badger Flats (Lake George) Area

The Badger Flats beryllium district (fig. 13, loc. 15, fig. 15) is in Park County, 12 miles northeast of Lake George, a crossroads settlement on U.S. Highway 24, 40 miles west of Colorado Springs.

It corresponds roughly to the earlier Mountain Dale Mining District and is referred to in recent Federal Geological Survey publications as the Lake George district (24, 43). Beryllium-bearing structures are also present in the adjoining Tarryall area.

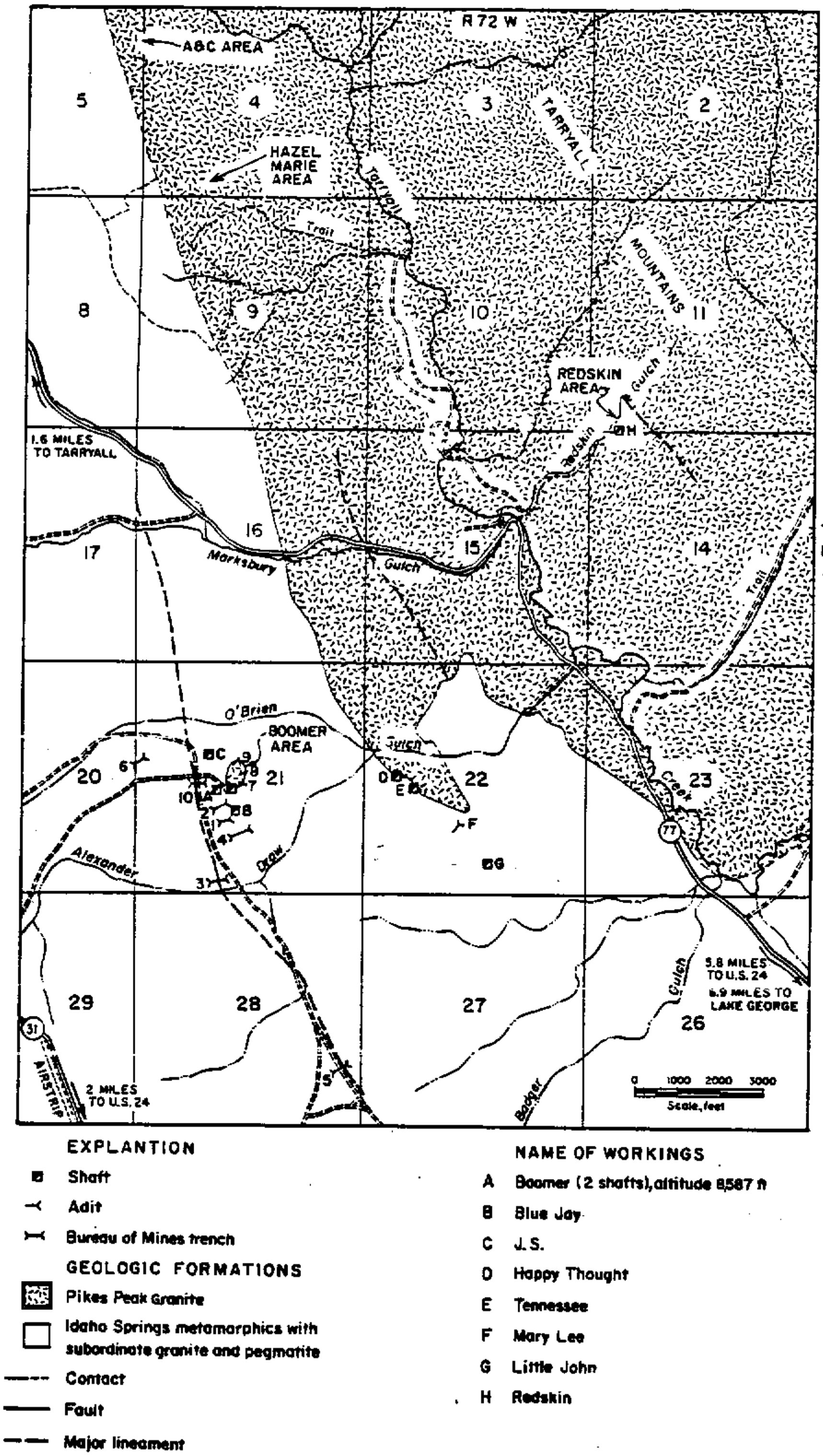

FIGURE 15. - Geological Features, Major Workings, and Bureau of Mines Trenches, Tarryall (Badger Flats) Beryllium Mining Area, Park County, Colo. (Base Map from U.S.G.S. Prof. Paper 400, Chapter B).

An unsuccessful gold rush at Tarryall in 1878 marked the first recorded mining effort in the area, followed in the next 75 years by unreward- prospecting and exploration for lead-silver, molybdenum, tungsten, and uranium. During the uranium period, beryllium minerals were found in the dumps of the Boomer mine, a lead-silver prospect dating from the 1890's, and this led, in 1955, to the discovery of high-grade vein-type beryllium ore in the old workings. The Boomer mine furnished a substantial part of domestic beryllium mineral production for several years starting in 1956, probably the first nonpegmatitic ore ever mined in commercial quantities.

The first ore bodies developed contained ore that met industry specifications (more than 8 percent BeO) as mined. While the original deposits have been depleted, other lower-grade deposits, containing from less than 1 percent BeO up to 5 or 6 percent BeO, have been found. In test runs at a flotation plant in the Tarryall area, mine ore was upgraded to a concentrate containing as much as 19.6 percent BeO. Concentrates from production runs averaged about 12 percent in grade. This concentrator has operated intermittently on a small scale since 1962, supplying an upgraded product to a beryllium oxide plant at Loveland, Colo.

An investigation of the area was carried on by the Bureau of Mines in 1959-60 with the objectives of tracing possible trends of beryllium enrichment connected with major structural lineaments suggested by Federal Geological Survey work (24), finding extensions of known ore bodies, and developing criteria of beryllium occurrence that would be helpful in further exploration. Mine workings were examined and sampled, as were pits and trenches that had been dug by prospectors during a period when hundreds of claims were being located. Trenching was also done by the Bureau when the desired exposures of bedrock had not been provided by other work (figs. 15, 16). Sampling and analysis by conventional means were supplemented by use of portable nuclear beryllium detectors to scan rock outcrops in place (fig. 16) and to test collected samples in the field, thus eliminating much of the delay entailed in waiting for sample returns from a distant laboratory.

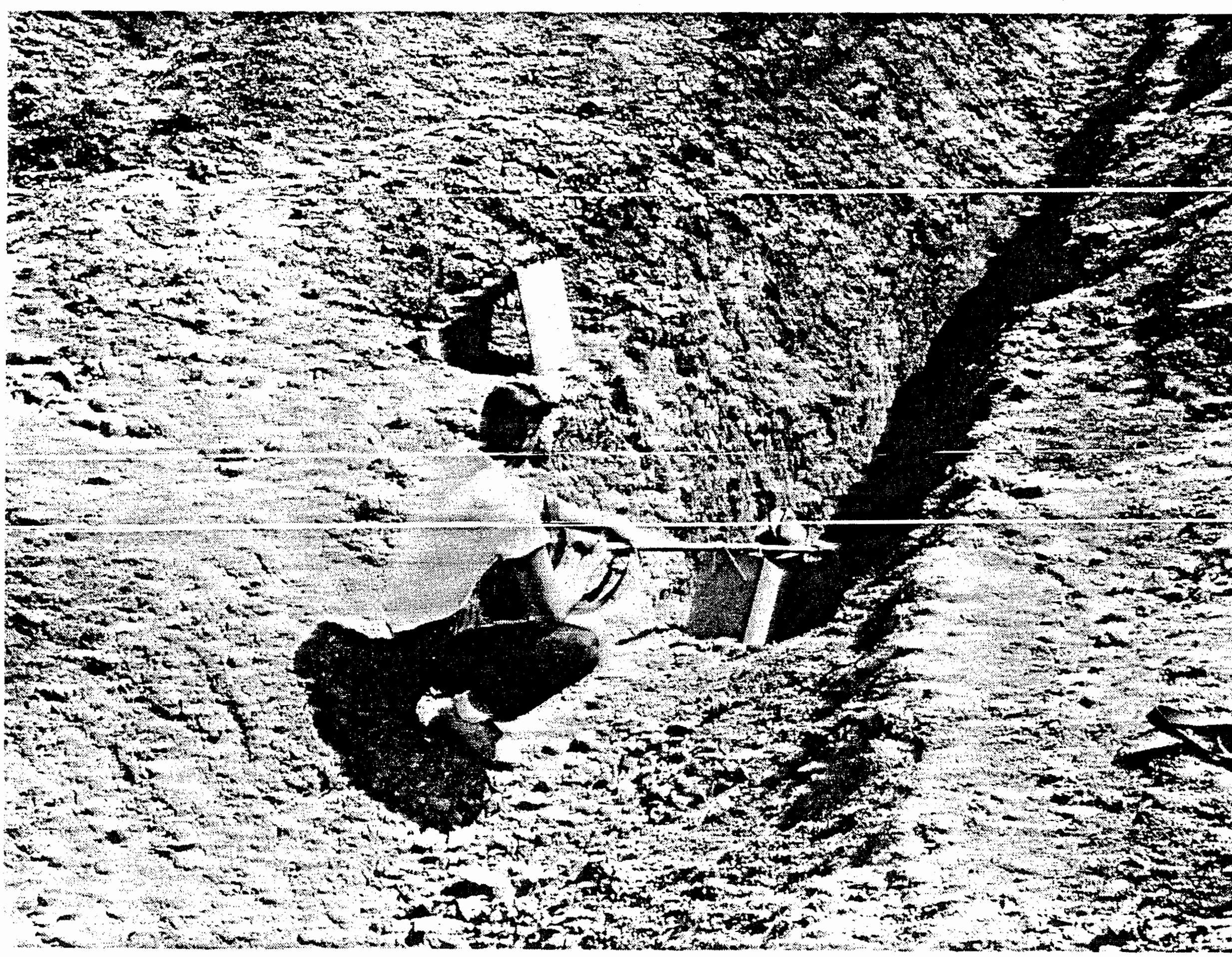

FIGURE 16. - Scanning Bedrock in Bureau of Mines Trench Using Portable Beryllium Detector, Boomer Area, Park County, Colo.

Description of the Deposits

The general geology of the area and descriptions of local rock structure and mineralogy are given in Federal Geological Survey publications (24, 35, 43). The major rocks of the Badger Flats area (fig. 15) are metamorphic units intruded by granite. The Boomer mine is in a comparatively narrow northwest-trending band of schistose and gneissic rocks of the Precambrian Idaho Springs Formation, the oldest in the area. This formation has been intruded by younger granite, also of Precambrian age, that forms the large Pikes Peak Batholith, represented in this area by the Tarryall Mountains northeast of Badger Flats, and by other small intrusive masses, one of which adjoins the Boomer mine workings. Innumerable small aplitic and pegmatitic masses and stringers have also been injected into the Idaho Springs Formation.

The important beryllium minerals present in the Boomer deposits, as well as elsewhere in the area, are beryl and bertrandite. Specimens of euclase have been identified. In some instances, bertrandite is the chief ore mineral. The beryl is easily identified by its crystal form, but bertrandite is inconspicuous and difficult to identify visually and nuclear beryllium detectors have been invaluable for testing doubtful material. Significant beryllium concentrations appear to be associated with greisenization.

Quartz is the chief gangue mineral. Other minerals identified in vein matter and mica-quartz greisen are fluorite, pyrite, sphalerite, molybdenite, wolframite, galena, chalcopyrite, arsenopyrite, muscovite, and sooty pitchblende. Fluorite is relatively abundant in greisenized rock and is used locally as an ore "indicator," although it does not have an invariable association with beryllium. The other minerals listed may be locally abundant but are generally scarce and sporadically distributed. Beryllium minerals are present in both granite and metamorphic rock, generally near contacts between different rock units, as in the Boomer mine. Significant concentrations of beryllium occur in greisenized vein matter and wall rock, although greisen without beryllium is also known. Greisen with a substantial content of beryllium minerals tends to have a distinctive yellowish cast due to altered fine-grained muscovite. This contrasts with a dark-gray color imparted by normal muscovite. However, yellow greisen without beryllium is also known locally.

The Boomer mine has been developed to a depth of 150 feet by two shafts and five levels of limited lateral extent. The major openings date from the lead-silver exploration period. Recent work consisted largely of rehabilitation and short extensions of existing level workings. Commercial ore has been limited to shallow depths (65 feet) and to a small area. Most of the production has come from the high-temperature Boomer vein deposits which occupy discontinuous and intersecting fractures in a shear zone along the southwestern contact of a small granite stock. Podlike ore shoots range from a few inches to a few feet in thickness; occasionally they are up to 10 feet thick. The larger pods are limited laterally and vertically to a few tens of feet. The largest ore body mined measured 30 feet laterally, 40 feet along the dip of the vein, and 10 feet in thickness. The ore appears to have been deposited in shear zones near formation contacts by mineralizing solutions that accompanied greisenization of both the vein matter and the country rock. The beryllium content of vein matter and wall rock decreases rapidly outside the ore shoots, and both vein matter and wall rock only a few feet away from a pod of ore normally show little greisenization or beryllium content.

Other Boomer Area Occurrences

Adjoining the Boomer property are other claims on which five shallow shafts have been sunk or rehabilitated. Of these, the Blue Jay and the J. S. No. 1 (fig. 15) shafts have encountered beryllium ore of limited significance. The ore resembles that found in the Boomer ore shoots but occurs in smaller concentrations.

The Blue Jay ore body is in a flat-lying greisen-quartz stringer a few inches wide that apparently was also cut in Bureau of Mines trench 2 (fig. 15). Beryllium minerals are present in the weathered bedrock mantle cut in this trench and suggest that formerly an up-dip extension of this flat vein to the Boomer vein system existed but has been removed by erosion.

The ore on the J. S. claim consisted of several small, isolated pods 50 to 70 feet below the surface in a steeply dipping vein developed by the No. 1 incline shaft. This vein projects as a possible northerly extension of one of the Boomer veins. Four tons of ore, averaging 9.25 percent BeO, was obtained by selective mining. Exploration, presumably on the same vein system, through two shallow shafts along the 1,000 feet between the Boomer mine and the J. S. No. 1 shaft did not disclose any significant beryllium occurrences.

Veins exhibiting some greisenization and sparse beryllium enrichment have been explored on the Happy Thought, Tennessee, Mary Lee, and Little John claims in the Idaho Springs Formation near the contact with the main Pikes Peak batholith. The general structural environment resembles that of the Boomer mine. A few tons of salable ore, saved from an adit driven along a small stringer on the Mary Lee claim, represents the only production from any of these properties.

Another type of beryllium occurrence in the area consists of random beryl-quartz stringers or veinlets a fraction of an inch wide in the country rock. These stringers are discontinuous, the contained beryl is sporadic in distribution, and greisenization is slight or absent. The veinlets are not abundant, although apparently widely distributed, and in no observed instances do they constitute significant occurrences.

Tarryall Occurrences

Several small beryllium deposits have been found in Pikes Peak Granite near Tarryall Creek. They apparently do not have the potential of the Boomer-type deposit but might be mined profitably under certain conditions, and, with development, might lead to larger ore bodies.

On the A & C claims, in secs 4 and 5 (fig. 15), pods of beryl and bertrandite in greisen are present in a flat-lying stringer up to 6 inches wide outcropping on a steep, granite hillside. The limits of the occurrence had not been established by the surface work done at the time of the Bureau examination. By careful selective mining and sorting, approximately a ton of material of about 8 percent BeO had been saved during open-pit excavation that extended about 15 feet into the hill along a 20-foot outcrop. Mining cost for this occurrence would be less, if a lower grade of ore were acceptable.

The Hazel Marie group in secs 4 and 5 (fig. 15) contains greisenized vertical stringers a few inches wide with pods of beryl and bertrandite. The ore was discovered by trenching through a thick mantle of weathered material containing beryllium-bearing float. The ore limits had not been determined by the limited exploration done through two prospect shafts 15 to 20 feet deep. About 2 tons of sorted beryl crystals had been sold to the Government buying station in Custer, S. Dak., and a few tons of sacked ore of lower grade were stored at the property. The occurrence, like that on the A & C claims, cannot be mined to produce high-grade ore at a reasonable cost.

No pattern of occurrence for the A & C and Hazel Marie deposits has been established. However, it is reasonable to assume that other similar occurrences are present in the area of unexplored granite adjoining the Idaho Springs metamorphic belt.

At the Redskin property in sec 11 (fig. 15, H) on the lower western slope of the Tarryall Mountains, bertrandite occurs in greisenized pipes or channels in Pikes Peak Granite. The example explored at the Redskin mine is a steeply dipping cylindrical body about 3 feet in diameter at the surface and of unknown vertical extent. It was explored for molybdenum during World War I through a 50-foot incline shaft, which was flooded at the time of the Bureau visit. Sampling of outcrop and mine dump indicated an average content of 5 percent BeO. The beryllium minerals apparently are confined to the pipelike body, and therefore the tonnage potential is limited. Other similar pipelike structures have been located during reconnaissance of the area by a number of investigators, and may have a wide distribution in the Tarryall Range.

Summary

No new deposits or significant extensions of known beryllium ore were found through Bureau work. The existence of at least one of several major structural lineaments suggested by geochemical work and mapping by the Federal Geological Survey was substantiated. This northwest-trending lineament passed near the Boomer mine, but a postulated structural relationship with the Boomer ore zone could not be verified.

Although ore in commercial quantities has not been developed outside of the Boomer property, the Badger Flats area, or Tarryall area, contains about 36 square miles of granitic rocks that are largely unexplored and favorable for occurrence of beryllium minerals. The presence of beryllium-bearing structures containing ore-grade or near-ore-grade material several miles from the Boomer deposit suggests that significant beryllium occurrences are not necessarily limited to the immediate area of the Boomer mine. A large unexplored area along the Tarryall Mountains appears to be favorable for such occurrences. A worthwhile potential for ore that might be minable under favorable conditions may exist, though individual deposits are likely to be small and production rates low.

On the basis of exploration to date, the probability of finding large, low-grade commercial beryllium deposits in the Badger Flats area seems to be remote. The typical beryllium occurrence observed in deposits is accompanied by a rapid transition from rich beryllium-bearing material in ore shoots to barren wall rock or barren vein matter. Halos of low-grade material around deposits have not been found.

St. Peters Dome Area

St. Peters Dome (fig. 13, loc. 22) is a prominent granite peak on the south flank of Pikes Peak in El Paso County. The area prospected for beryllium is west of St. Peters Dome, in El Paso and Teller Counties. The area adjoins the Wye campground, a point on a forest service road constructed on an abandoned railroad grade, 21.4 miles from Colorado Springs.

A beryllium mineral, tentatively identified as bertrandite, has been found in red, iron-stained, shear structures in Pikes Peak Granite near an intrusive mass of Mount Rosa Granite (15). The bertrandite occurs with thorium and possibly rare earth minerals as blebs and stringers in an altered shear material. Beryllium is present over a substantial area and, as found locally, in small, sporadic enrichments; no continuity laterally and in depth has been established. An area of several square miles has been prospected. Intensive exploration by surface excavation and drilling has been limited to the Comanche claims.

Comanche Group

The Comanche claims (fig. 13, loc. 21) are located in section 13 at the end of a 1-mile access road north from the Wye campground.

A shear zone in Pikes Peak Granite has been stripped over an area about 50 by 75 feet and further exposed by benching a steep hillside to a maximum depth of 15 feet. Boulders of altered shear material, weighing up to 50 pounds each, scattered about the workings were reported to be found in place near bedrock surfaces. A sample chipped from a 15-pound boulder contained 6.43 percent BeO by Bureau activation analysis. However, no beryllium remained in working faces tested by scanning rock in place with a portable detector (fig. 17). Several drill holes were reported by an operator to have intersected narrow beryllium-enriched zones. Drilling data were condifential.

New Mexico

The locations of 15 New Mexico properties examined are shown in figure 18.

Cornudas Mountains Deposit

The Cornudas Mountains (fig. 18, loc. 7) are in southern Otero County, N. Mex., and adjoining northern Hudspeth County, Tex.

FIGURE 17. - Scanning Granite in Excavation Wall Pit With Portable Beryllium Detector, St. Peters Dome Area.

Permission must be obtained to travel the private roads that lead to the area, 48.6 miles east of El Paso, Tex., on U.S. Highway 62-180.

Eleven prominent, isolated peaks, ranging in height from 600 feet (Deer Mountain) to 2,500 feet (Wind Mountain), rise above the relatively flat Diablo Plateau within a 9-mile square area.

Individual peaks, roughly circular in plan, are denuded cores of laccoliths that intruded and domed Permian-Pennsylvanian sediments (40). The intrusive rock is nepheline syenite that varies in texture from trachytic to pegmatitic. Nepheline crystals comprise up to 20 percent of the rock volume.

Around the peaks are numerous, narrow syenite dikes that occupy fissures radiating out from the laccolithic cores. The remnants of the domed sedimentary structures around each peak dip 50° to 80° away from their circular contact with the syenite cores. Tilting of the beds is still evident some 2,000 feet from the contacts where the dips are 20° to 50°, flattening to 5° to 15° at 4,000 feet.

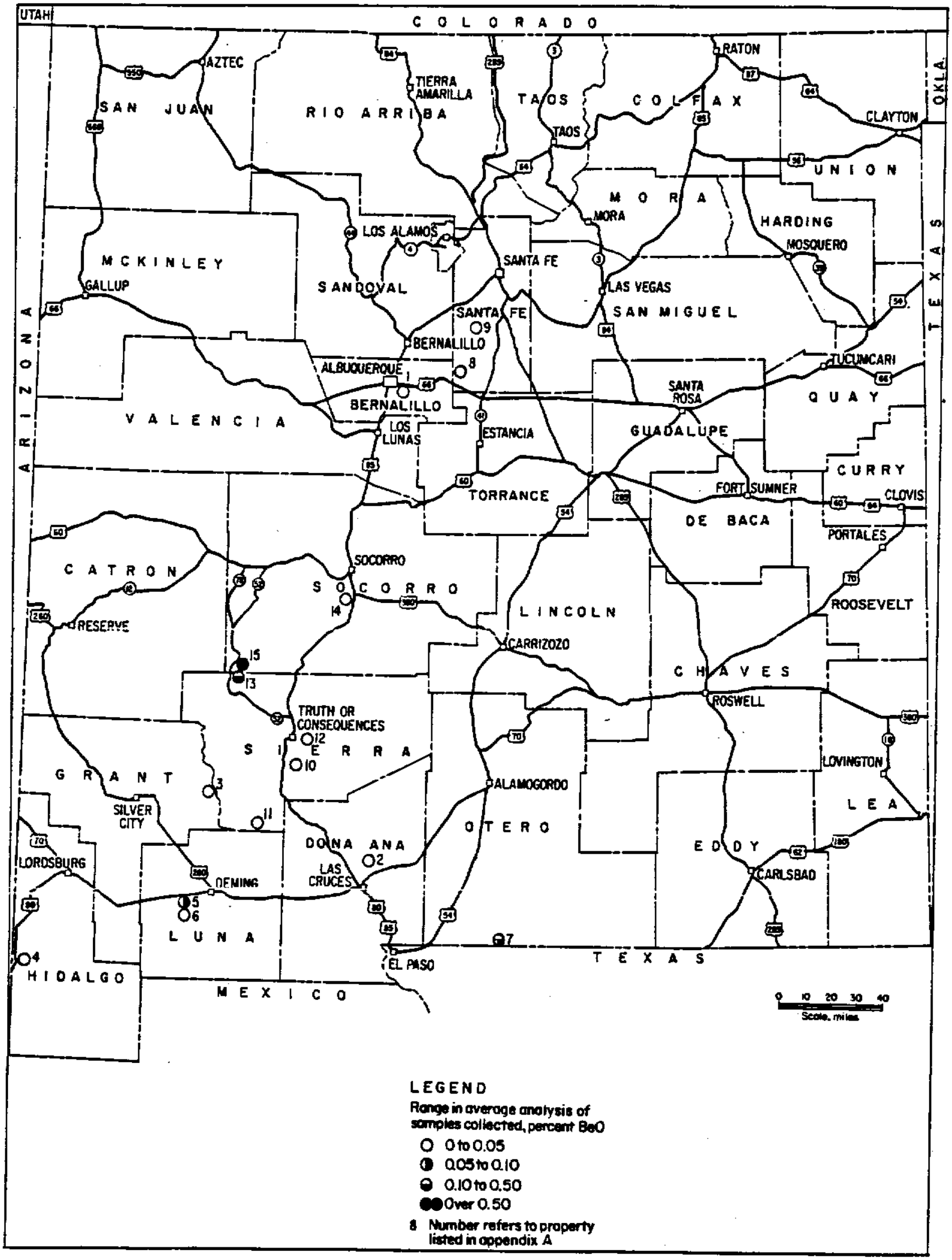

FIGURE 18. - Location of Properties Examined for Beryllium in New Mexico.

Beryllium minerals from the Cornudas Mountains that have been identified are euclase, eudidymite, and tentatively, bertrandite. Beryllium has been detected in most of the intrusive outcrops. Generally, the coarser the crystallization of the rock, the higher the beryllium content. Samples collected by the Bureau of Mines and other investigators range from 0 to as much as 0.20 percent BeO, with an average of approximately 0.10 percent BeO.

Spectrographic analyses of samples from some specific locations (Cornudas Mountain, Wind Mountain, San Antonio Mountain, and Chatfield Mountain) have indicated interesting amounts of lithium, rubidium, gallium, yttrium, tin, nickel, zirconium, and columbium.

The area has been developed through numerous shallow shafts, small prospect pits and trenches, and bulldozer cuts. Although probable ore grade is extremely low, the widespread occurrence of beryllium minerals suggests that the total beryllium content of the millions of tons of favorable intrusive rocks available is large.

Warm Springs Beryllium Deposit

The Warm Springs beryllium deposit (fig. 18, loc. 15) is on land held partly in fee and partly by location in the abandoned Warm Springs Apache Indian Reservation, southwestern Socorro County. The property is 23 miles north of Winston on New Mexico Highway 52, and 2.5 miles north of the Iron Mountain area. The deposit has been explored by a private company.

A major north-trending normal fault with downthrow to the west has brought conglomerates and sandstones of the Santa Fe Group of the Gila Conglomerate (41) west of the fault in contact locally with interlayered dark rhyolites and rhyolite-tuff agglomerates of the Rubio Peak Formation (fig. 19). A small hill about 25 feet high just east of the fault is capped by a beryllium-bearing remnant of the hydrothermally altered rhyolite-tuff agglomerate. Beryllium enrichment in this remnant is exposed over an area approximately 10 by 20 feet.

The deposit has been explored by 7 trenches, a maximum of 5 feet deep, and 18 dry rotary drill holes, a maximum of 200 feet deep (figs. 19 and 20). The drilling has been done on both sides of the fault in randomly spaced holes, 10 to 70 feet apart, over an area about 180 by 250 feet. Drilling depth was limited by the water table, which prevented further drilling by the method used. The range in depth to water in the various holes indicates the existence of several perched water tables, possibly resulting from step faulting parallel to and west of the main fault.

Six drill holes in the trenched area penetrated the surface ore and cut additional ore-bearing units at depth. On the basis of drilling data and trenching, the surface ore body ranges between 10 and 35 feet in thickness, averaging 17 feet. The beryllium-bearing intervals cut at depth range from 5 to 45 feet thick. The mineralized drill cuttings obtained resemble the ore at surface, and it can be assumed that these deeper ore intervals represent similar rhyolite-tuff agglomerate units. Estimates of their thickness were based on analyses of drill cutting samples taken in 5-foot intervals.

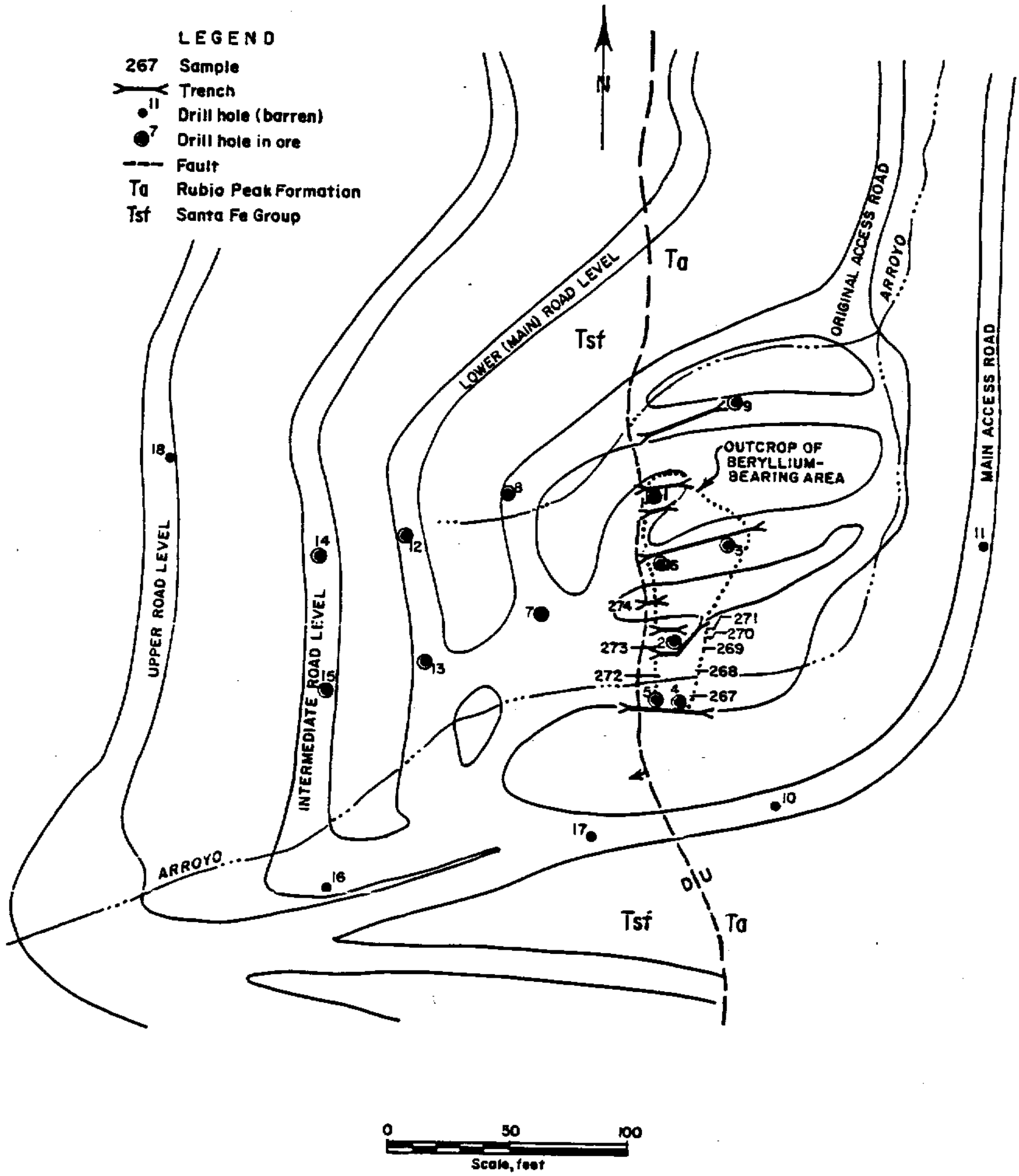

FIGURE 19. - Surface Workings, Warm Springs Beryllium Deposit, Socorro County, N. Mex.

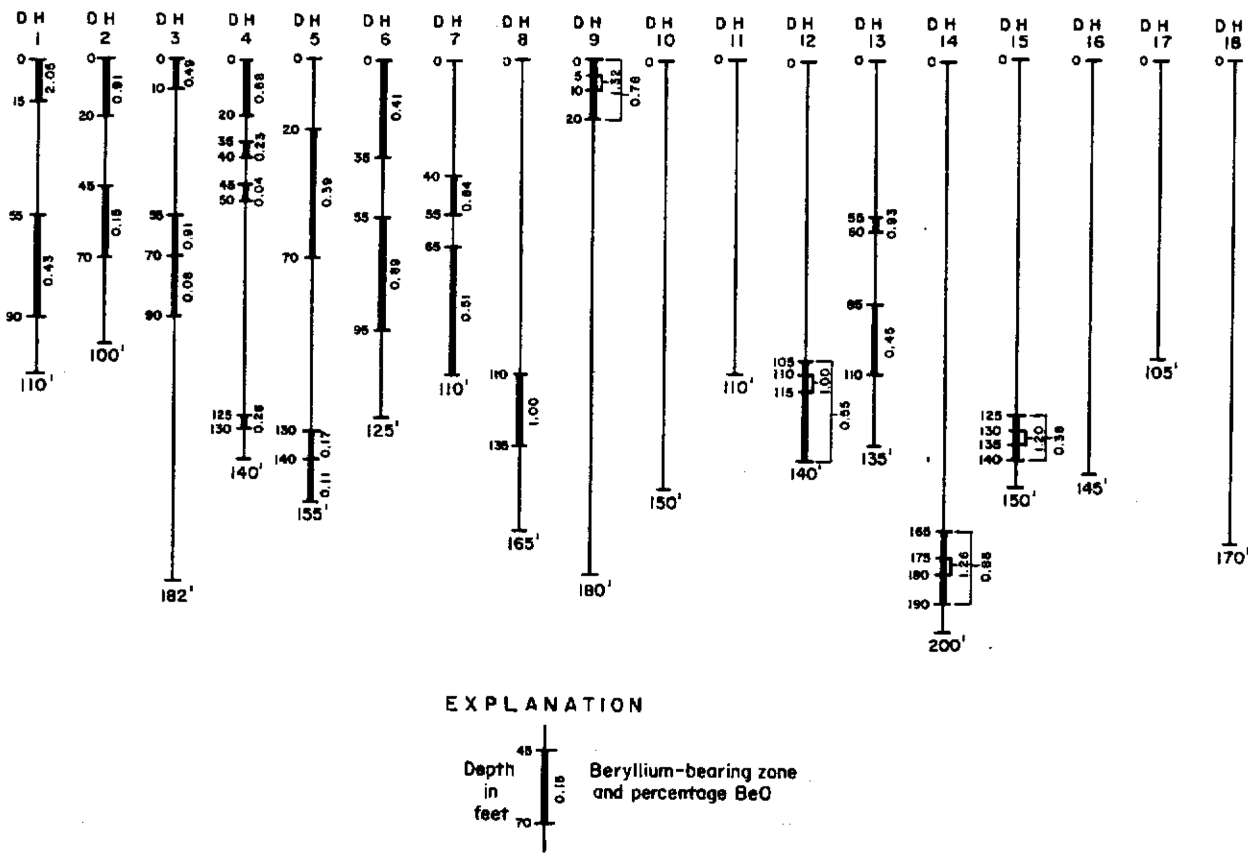

FIGURE 20. - Drill Hole Logs, Warm Springs Beryllium Deposit, Socorro County, N. Mex.

The erratic character of the several ore-bearing units both in thickness and in depth below the surface, as indicated by these results, does not permit a good correlation of the ore horizons. Some holes cut one ore interval, others two, and one hole (No. 4) cut four. The surface ore exhibits an appreciable range in thickness and beryllium content within a few tens of feet laterally, and drilling results suggest that the deeper ore horizons have similar characteristics. The throw of the fault or faults is unknown, making correlation between drill holes on opposite sides of the fault zone uncertain. The ore intervals cut in the drill holes in the downthrown block to the west may represent down-faulted continuations of ore horizons that have been removed by erosion east of the fault. If this is true, down-faulted segments of the known ore horizons east of the fault are below the horizon reached by drilling west of the fault.

Samples of drill-hole cuttings and trench exposures were analyzed by a private individual using nuclear detection methods. Results are shown on figure 20. During the Bureau of Mines examination, the surface was scanned with a portable beryllium detector. Background count was high in the outcrop area and no quantitative evaluations could be made directly on the outcrops. Eight samples were taken in narrow trenches about 2 feet deep cut at locations shown in figure 19. Results were as follows:

Sample:	BeO, percent
267............	1.60
268............	.65
269............	.33
270............	.29
271............	.17
272............	2.00
273............	.83
274............	.25

These analyses are in the same range as those made on drill cuttings by a commercial laboratory.

While the known surface ore in the Warm Springs area is limited, the existence of a more significant resource at depth is indicated. Exploration results point to substantial ore thicknesses and an average grade between 0.50 and 1.00 BeO. This might constitute minable ore under favorable economic conditions.

Iron Mountain District

The Iron Mountain district (fig. 18, loc. 13) occupies an area of about 15 square miles in northwestern Sierra and southwestern Socorro Counties. The area is 51 miles northwest from Truth or Consequences over U.S. Highway 85 and New Mexico Highways 52 and 59. A 3.5-mile mine-access road east from New Mexico Highway 59, about 11 miles north of Winston, leads to the beryllium-bearing area.

The iron-rich formations of Iron Mountain have been explored chiefly for magnetite but also for tungsten, gold, base metals, and beryllium. No commercial production of beryllium has been made.

Iron Mountain proper is a fault-block ridge composed of contact metamorphic rocks. Limestones and calcareous shales have been altered in part to tactite near intrusive masses of rhyolite, granite, and aplite. The known beryllium-bearing formation is a variety of tactite called ribbon rock, found in the northern third of the mountain. Beryllium occurs chiefly as helvite and as a minor impurity in grossularite, idocrase, and chlorite. Beryllium minerals do not occur in the large massive tactite bodies of the area but in a distinctive layered ribbon rock in which dark iron-rich layers alternate with layers of lighter color. Major constituents of the ribbon rock are magnetite and fluorite. Ribbon rock occurrences normally are found along the contacts of massive tactite bodies and limestone, forming thick pods, pipelike masses, and thin tabular bodies. However, they are of limited extent compared to the massive tactites.

Strategic mineral investigations for beryllium and tungsten were carried on in 1942-43 by the Federal Bureau of Mines (37) and Geological Survey (25). These included geologic mapping, sampling, trenching, diamond drilling, and underground exploration. Calculated reserves based on the work included 3,500 tons of iron-rich ribbon rock containing an estimated 0.7 percent BeO as helvite, and 84,000 tons of silicate-rich ribbon rock containing 0.2 percent BeO as danalite and other minerals. Additional reserves of 1,000 tons of the richer ore and 100,000 tons of the low-grade ore were inferred. The conclusion was reached that there was little additional reserve potential because the beryllium-bearing formations were probably cut off at a shallow depth by igneous rock.

Investigation by the Bureau in 1961 was limited to taking character samples of different rock types for study and analysis. Beryllium was found only in specimens of ribbon rock (0.18 and 0.15 percent BeO). No revision of the earlier reserve estimates was indicated.

Utah

Figure 21 shows the location of 34 properties investigated in Utah.

Miller Mine

The Miller property, on the eastern flank of the Mineral Range, consists of 30 unpatented mineral claims in Beaver County (fig. 21, loc. 5).

The property was probably explored originally for tungsten. Scheelite, helvite, and minor beryl occur in tactite zones between faulted limestones and a granite stock. The irregular contact is obscured by a thick soil mantle.

Mine workings comprise a 130-foot vertical shaft with one level at the bottom and a 122-foot inclined shaft with lateral workings 25 feet below surface (fig. 22). The incline shaft is connected to the 130-foot level of the vertical shaft but has been backfilled up to the 25-foot level. Several small pits and trenches have been excavated near the main workings. In 1960, a private operator put down five diamond drill holes in the area around the shaft.

The beryllium mineral, helvite, that led to the recent exploration, was found in brecciated material in a small dump from the inclined shaft. Twelve samples assayed from 0.07 to 7.6 percent BeO. No beryllium was visible in the limited exposures of rock on the 25-foot level of the incline shaft although a sample of material in the top of the backfill, apparently from work done above this level, assayed 0.97 percent BeO.

The drill holes gave only negative information, so far as could be learned. In 1961, an exploratory lateral at the 130-foot level of the vertical shaft was driven southeastward in brecciated material (fig. 22). A small southwest-trending stringer, cut at a point 80 feet from the shaft, contained a pod of beryllium that was sampled during a Bureau reconnaissance of the new workings. This sample, which appeared to be unique, assayed 7.6 percent BeO. No other pods were seen, and four other samples taken on the 130-foot level were barren or nearly so. To date, ore of the tenor found in the dump from the incline shaft has not been found in place. On the basis of the very limited amount of exploration done, the potential of the property, while apparently limited, cannot be estimated fairly.

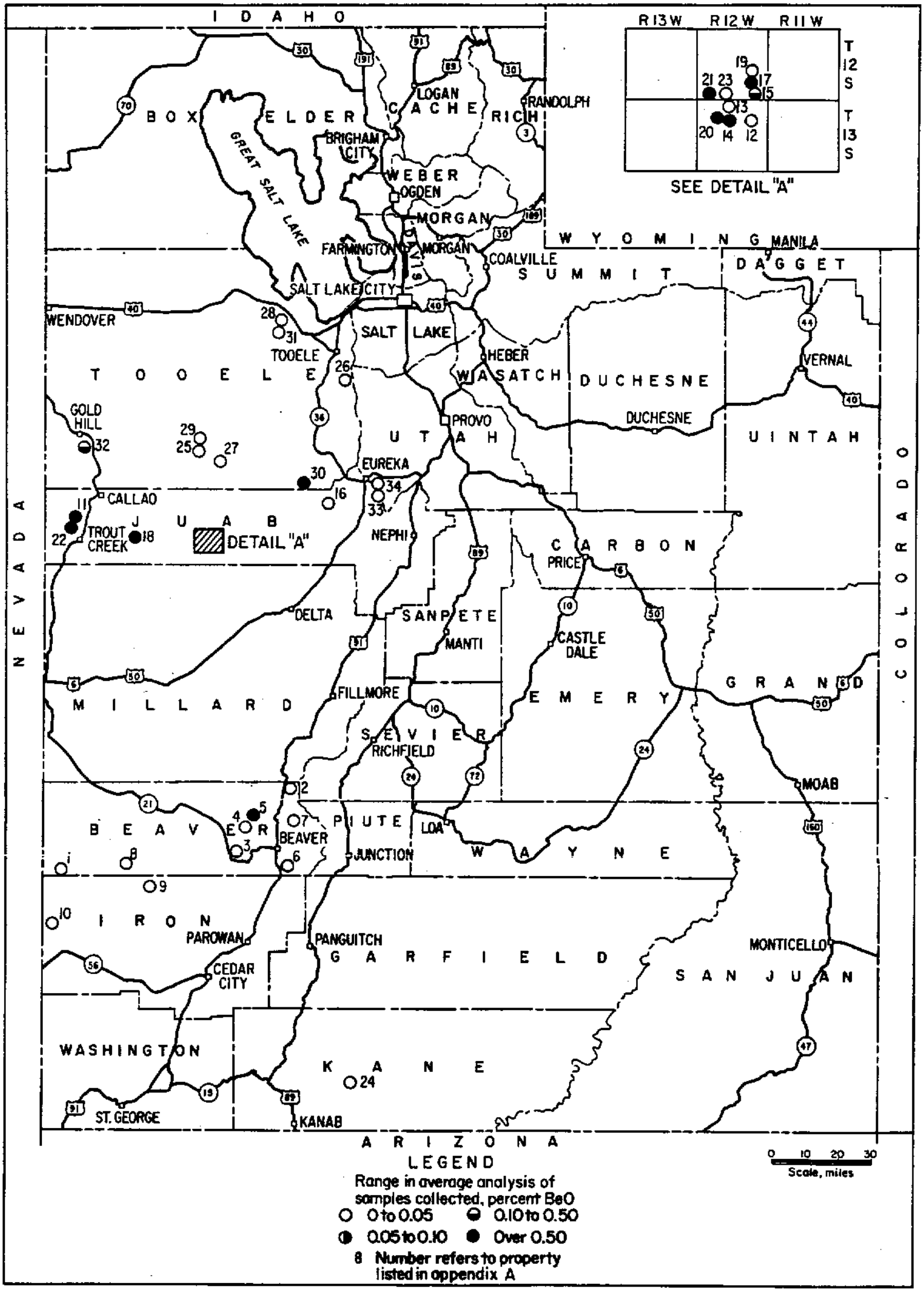

FIGURE 21. - Location of Properties Examined for Beryllium in Utah.

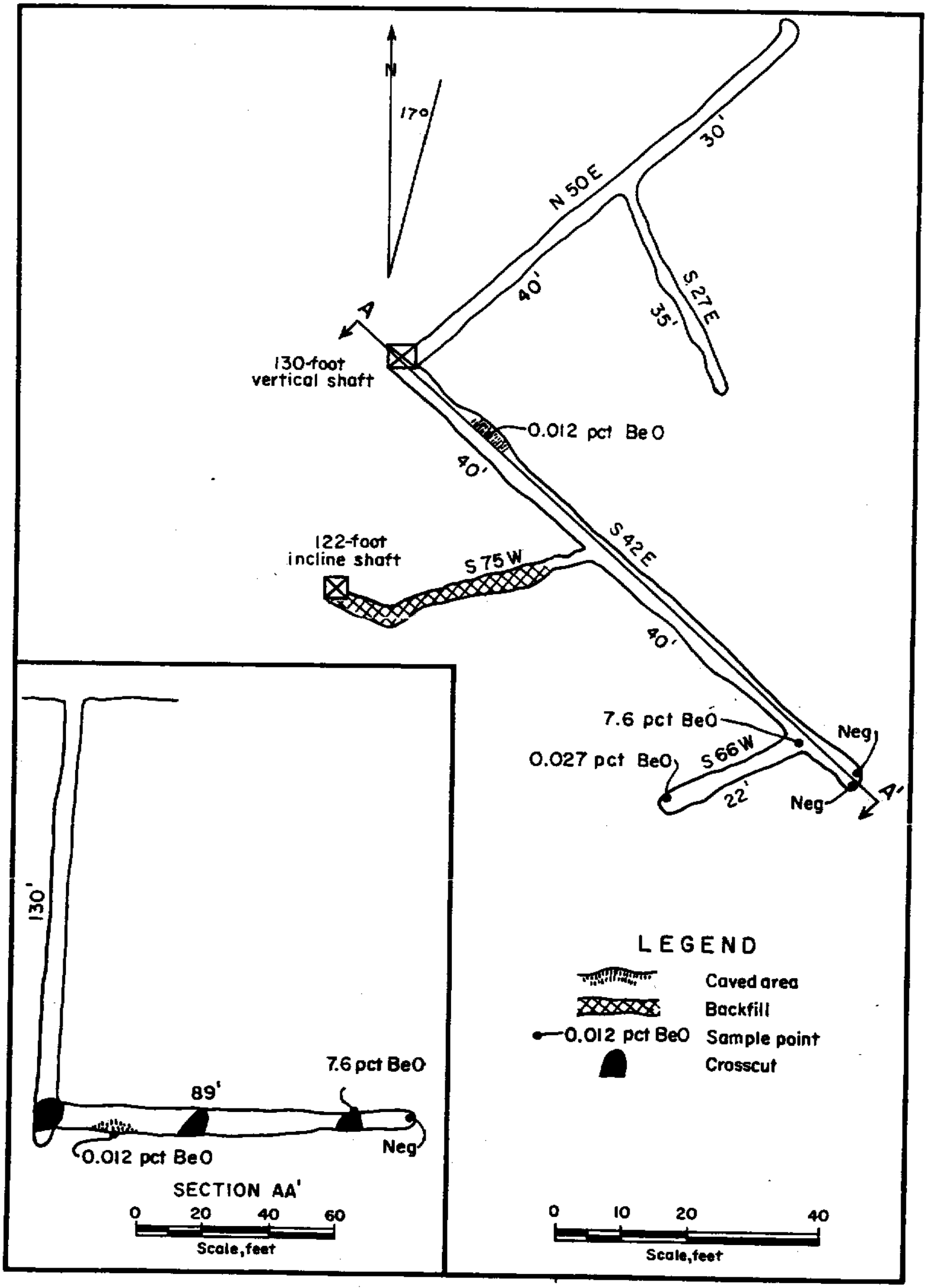

FIGURE 22. - Sketch Map of Miller Mine, Beaver County, Utah.

Apex Tungsten Property

The Apex tungsten property (fig. 21, loc. 11) consists of 25 contiguous claims, 4 patented, in Juab County near the Utah-Nevada border.

The principal beryllium-bearing rock unit on the property is a metamorphosed limestone about 50 feet thick containing several thin interbedded shales. This unit is overlain and underlain by thick phyllite beds. Quartzite beds about 4 feet thick occur at both the upper and lower limestone-phyllite contacts.

The entire sedimentary series is in a tilted complex fault block. Two systems of shearing, one trending westward roughly parallel to the general strike of the beds and the other northerly, have segmented the block. These shear systems dip 65° to 80° N and 40° to 50° E respectively. Fault movement along both shear zones has dropped segments of the formations generally downward to the north and east in small steps. One exception is an observed instance where the displacement was downward to the west.

On the basis of exploration to date, the best potential beryllium-bearing rock unit is the limestone in which most of the tungsten prospecting was done. However, several beryl-bearing veins up to 2 feet wide and averaging 8 inches thick in phyllite were exposed by surface workings. Sporadic clusters of beryl crystals also have been found in phyllite outcrops.

Mineral deposition is attributed to contact metamorphism associated with nearby intrusives. Scheelite, fluorite, and beryl were deposited in small quartz- and greisenized-fissures in both shear systems in limestone. Individual ore segments are short, being interrupted by fault displacement. Beryllium and tungsten replacements in the walls of fissures have been noted, with penetration in limestone up to 4 feet and in phyllite up to 2 feet.

Exploration was done for tungsten through underground workings at the Apex and Merry mines and in surface workings (fig. 23). Privately financed work to investigate the deposits for beryllium consisted of geologic mapping, examination of workings, excavation in the course of building access roads and stripping certain outcrops, and drilling of 18 vertical noncore drill holes. Holes averaged 100 feet deep, with one hole 240 feet deep.

During the Bureau investigation, surface and underground workings were sampled and, where feasible, rock exposures were scanned directly with a portable beryllium detector. Results obtained underground and in certain surface exposures are shown on figure 23. Several hundred random tests were made by scanning limestone and phyllite outcrops with a portable detector over an area approximately 300 by 800 feet. Generally, beryllium was sparse over the area; however, some detector readings ranged up to 4.46 percent BeO. Beryl crystals usually were visible in material that contained 0.2 percent BeO or more.

The operator's analytical results on drill cuttings from holes, randomly spaced from 30 to 500 feet apart, were low. Cuttings left at the hole sites were scanned with the beryllium detector, giving essentially negative results.

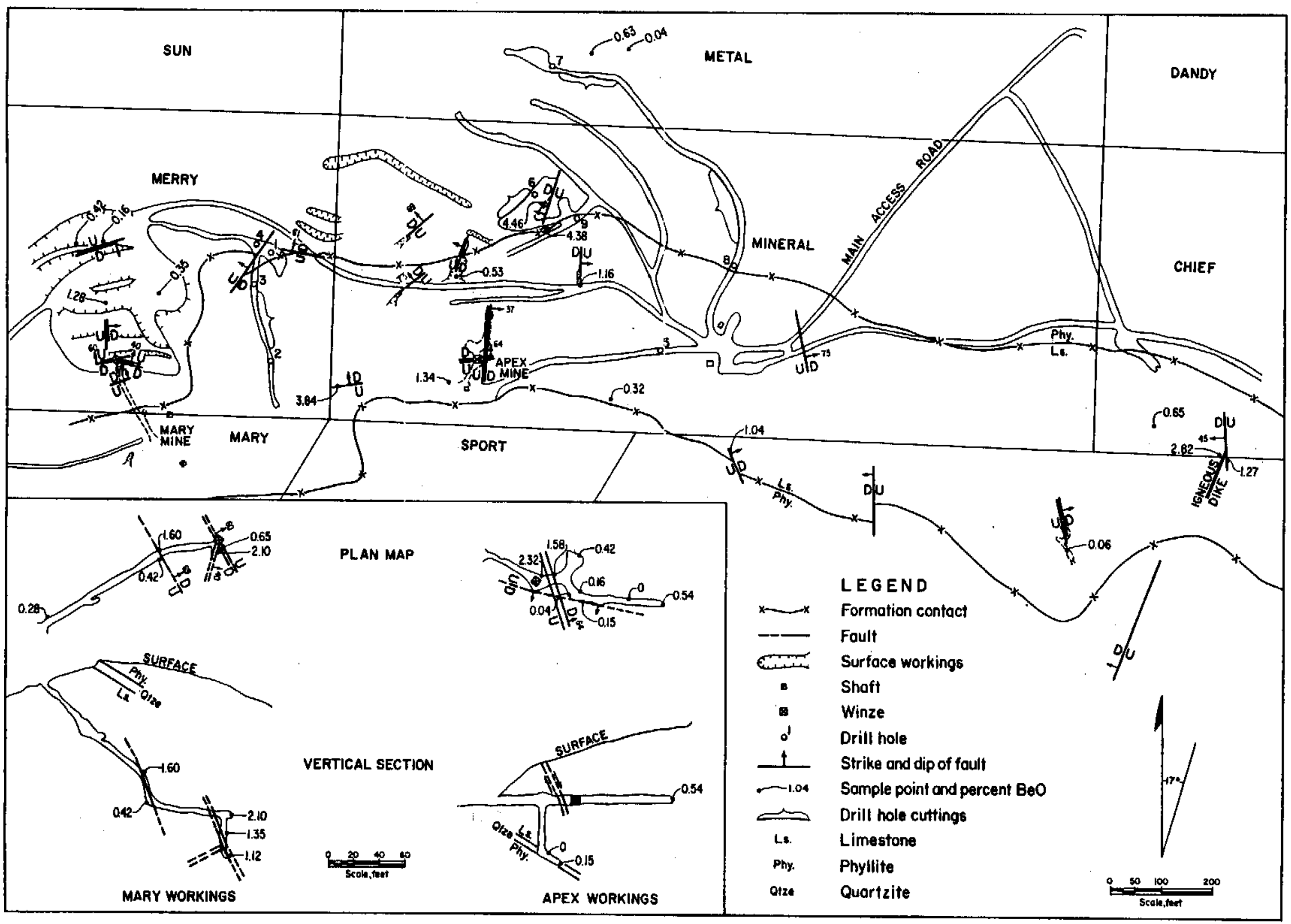

FIGURE 23. - Workings, Apex Tungsten Property, Juab County, Utah. *(Base Map, Courtesy, John Schumacher, Lessee, M. S. Babick, Owner).*

The results of the Bureau investigations indicate that minable units of beryllium ore, measuring up to 50 feet laterally and vertically and 1 foot thick, exist in the limestone. The limestone extends for at least 2,300 feet northeasterly on the Apex property and possibly southwest into adjoining ground. The amount of beryllium contained in a single ore unit is small, but the extent of the favorable limestone indicates that the potential is significant. Ore grade would probably not exceed 1 to 2 percent BeO, as mined, well below salable grade under current industry specifications.

Drilling results and examination of outcrops indicate that the beryllium content of either limestone or phyllite, taken as a whole, is low, possibly not exceeding 0.1 percent BeO, and probably precludes any large-scale mining operation. The possibility exists that, under favorable economic conditions, both beryllium and tungsten could be recovered by mining the small limestone ore units individually and milling to produce separate concentrates.

Spor Mountain Deposits

In December 1959, unique beryllium deposits (fig. 21, detail A) were discovered at Spor Mountain, a prominent isolated ridge west of the Thomas Range, 40 miles by graveled road northwest of Delta.

Commercial fluorite deposits in the Spor Mountain area have been worked since World War II. Current exploration for beryllium has been done on extensive beryllium-bearing rhyolitic-tuff outcrops on the lower western slope of Spor Mountain. However, some attention has been given to similar but limited occurrences east of Spor Mountain.

Extensive exploration by noncore drilling and mechanized surface excavation has been accomplished by both major mining organizations and small groups. Much of the activity has been consolidated into operations by a few large companies. Litigation, resulting from many ownership conflicts that developed during the intensive claim-locating activities, has been or is being resolved.

Most of the exploratory work has been done on deposits that extend westward under the flat desert terrain of Fish Springs Valley. Results of exploration elsewhere around Spor Mountain are inconclusive. Indicated and inferred reserves in the deposits west of Spor Mountain total millions of tons of ore with an estimated average grade of 0.5 percent BeO, some of which can be exploited by open-pit methods. The total resource potential is substantially larger.

Production of ore in the Spor Mountain area has been limited to mining bulk samples from open pits for metallurgical testing. Results of research in laboratory and pilot plant work by private operators and the Salt Lake City Metallurgy Research Center of the Bureau of Mines indicate that a usable beryllium chemical can be extracted directly from the ore by hydrometallurgical methods (13-14, 17-18, 30, 32).

The beryllium-bearing rhyolitic tuff of the Spor Mountain area (fig. 24), also classified as a tuffaceous agglomerate, occurs in a series of rhyolite flows, welded tuffs, and agglomerates of Tertiary age laid down on Paleozoic Formations (36). The largest exposures of ore-bearing tuff are along the western base of Spor Mountain; similar mineralized tuff beds have been found in Dugway Dell, a valley between Spor Mountain (to the west) and Topaz Mountain (to the east). The western outcrops, trending generally northeast, can be traced along the west flank of Spor Mountain for 4 miles. The tuff beds dip 15° to 25° NW, plunging beneath Lake Bonneville sediments in Fish Springs Valley. Ore horizons have been found at depths up to 900 feet in drill holes 2.5 miles west of the outcrops. However, the volcanics do not lie in a simple monocline, a fact indicated by differences in depth to the ore horizon in adjoining drill holes. Extensive faulting, with alternately elevated and depressed fault blocks, interrupts the continuity of beds and ore horizons. Near Spor Mountain, tuff outcrops are repeated by faulting.

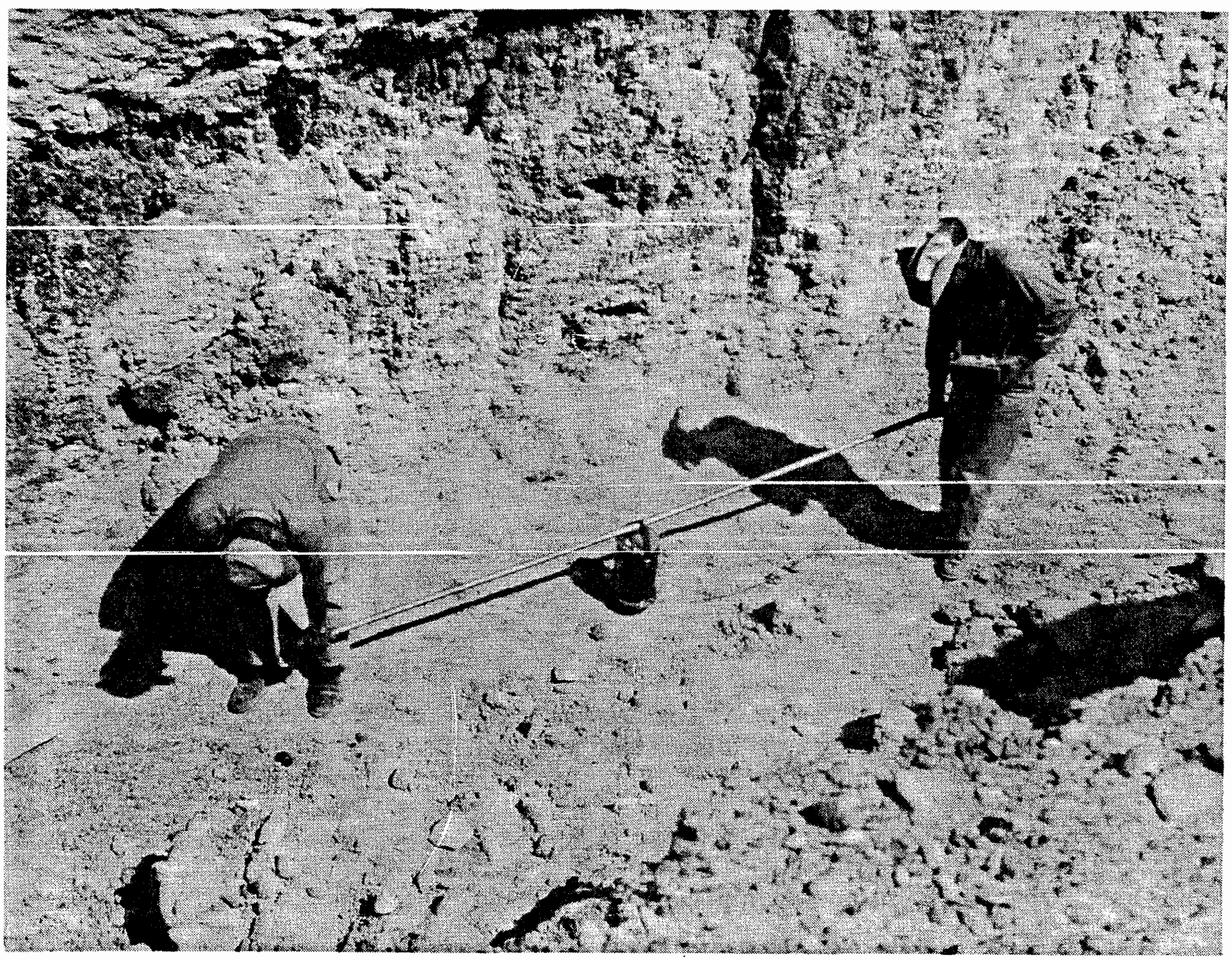

FIGURE 24. - Typical Beryllium-Bearing Tuff Bed in Walls and Floor of Bulldozer Trench.

Although beryllium has been found in several tuff beds, significant ore appears to be concentrated in a layered tuff unit 25 to 150 feet thick, near the base of the volcanic series overlying a dolomite, the topmost sedimentary unit. No beryllium has been found in rhyolite or welded tuff. The ore deposit, considered as a whole, has a wide areal extent, but is segmented by faulting. Shifting of the major ore horizon within the tuff produces further discontinuities apparently not connected with faulting.

The beryllium mineral in the Spor Mountain deposits has been identified as bertrandite in opaline fluorite nodules occurring in an altered, clayey, rhyolite tuff. The nodules contain as much as 7 percent BeO and are easily identified visually. Other minerals present in the tuff are montmorillonite, quartz, chalcedony, feldspar, sanidine, gypsum, calcite, mica, and iron- and manganese-oxides. Trace amounts of many metallic elements have been detected spectrographically.

Bureau of Mines investigations of the area started at existing ore exposures west of Spor Mountain to familiarize personnel with the recognizable characteristics of this unusual beryllium-bearing material. Nuclear detecting, using a portable instrument directly on outcrops, was a valuable aid. Later, work was extended to Dugway Dell, where an erosional remnant of similar ore-bearing tuff (Bell Hill Deposit) and an occurrence isolated by faulting (Claybank Deposit) have been found. Nine outcropping tuff beds on the slopes of Spor Mountain, the floor of Dugway Dell, and the wide, rising approach to Topaz Mountain were examined. No new occurrences were located during this work. Private drilling in the floor of Dugway Dell has also given essentially negative results. The significant beryllium reserves appear to lie west of Spor Mountain.

Even though the deposits west of Spor Mountain have a very large tonnage potential, the faulted structures, the shifting of ore layers within the mineralized tuff bed, and the low average beryllium content complicate the mining problem. However, open-pit methods can undoubtedly be devised for the shallow portions. An experimental underground operation has been set up by one of the large operators to develop a method for mining deep ore.

Honeycomb Hills

The Honeycomb Hills are two rhyolite plugs that rise above the desert floor in Snake Valley, just north of the county road, 30 miles west of Spor Mountain (fig. 21, loc. 18). The plugs are surrounded and underlain by flat- to gently-dipping, poorly bedded, light reddish-brown tuffaceous agglomerates. Quaternary lacustrine beds around the hills probably conceal extensions of the agglomerates.

The Honeycomb Hills have been explored for uranium and, possibly in an earlier period, for precious metals. Two short adits have been driven in an agglomerate near the western base of North Honeycomb Hill. A longer adit has been driven in the rhyolite of South Honeycomb Hill. These underground workings do not intersect beryllium occurrences.

Beryllium has been found in tuffaceous outcrops at several locations on the west side of North Honeycomb Hill, on the east side of South Honeycomb Hill, and on a low connecting ridge. Two of the beryllium-bearing exposures are worthy of note. A 20-foot-long and 5-foot-wide level area adjacent to the western base of North Honeycomb Hill contains beryllium-bearing tuffaceous agglomerate at least 5 feet thick. Scanning of this area with a portable beryllium detector indicated a small tonnage with an overall average of 0.2 percent BeO.

The other exposure, on the west slope of the ridge between North and South Honeycomb Hill, was delineated by a portable beryllium detector survey to be an area approximately 400 feet long, 200 feet wide, and 45 feet thick that contained sporadic beryllium. A portion of this area, 75 feet wide, 125 feet long, and 30 feet thick, contained higher-grade beryllium-bearing tuff. This higher grade tuff was surrounded by a manganese-stained zone approximately 15 feet wide. Development in the immediate area of the higher grade zone consisted of three small prospect pits and two rotary drill holes. Six samples collected from this area contained BeO in a range between 0.41 and 2.0 percent. The beryllium mineral from this zone was identified by the Bureau (29) as a hydrous beryllium hydroxide in a basic, homogeneous, red tuff composed almost entirely of volcanic glass.

A spectrographic analysis of a composite sample from the Honeycomb Hills indicated the presence of cesium, columbium, and rubidium.

Sheeprock Mountains Claims

The Sheeprock Mountains claims (fig. 21, loc. 30) cover approximately 6 square miles in a granite range in southeastern Tooele County. Clustered and irregularly disseminated beryl crystals occur in a light-colored granite; the known beryl-bearing area is about 3 miles long, 2 miles wide, and probably ranges over a vertical distance of 1,000 feet.

Three adits, all in granite, have been driven into the north slope of Hardluck Canyon. The upper adit is 725 feet long, the middle adit 50 feet long, and the lower adit 255 feet long. Material from the three adits has been stored in marked stockpiles along the floor of the canyon. A survey of the stockpiles with the portable beryllium detector indicated very little beryllium. A sample from the upper adit stockpile (406 to 411 feet) contained 0.02 percent BeO. Another sample from the upper adit (274 to 288 feet) contained 0.005 percent BeO. Other stockpiles gave negative results.

The walls of the upper adit were scanned with a portable detector. Sparsely distributed beryl clusters, blossoms, or individual beryl crystals were visible in the exposures. Scanning indicated that visible beryl is present when a significant beryllium content is detectable. A sample containing a visible beryl cluster and two samples without visible beryl, but which produced a slight count on the instrument, were returned for laboratory analysis with results as follows:

Sample:	BeO, percent
Right rib, 244 to 249 feet..........................	0
Left rib, 244 to 249 feet..........................	0
Left rib, 277 feet, 3-1/2 feet above track, limonite-stained beryl pod..........................	3.65

These results supported the conclusion that Sheeprock Mountain granite samples with a significant beryllium content always contain visible beryl. The Sheeprock deposit eventually may be of interest because of the large amount of low-grade beryllium-bearing material available.

Vanguard Research Property

The Vanguard Research property comprised located and patented claims covering 23.48 square miles in western Tooele County (fig. 21, loc. 32), 5.9 miles southwest of Gold Hill.

Complexly faulted, undifferentiated sedimentary rocks of Carboniferous age form the northern portion of the Deep Creek Range. A stock of sericitized and chloritized quartz monzonite intruded the northeastern portion of the range. The area is part of the Gold Hill mining district which was developed for gold, silver, lead, zinc, arsenic, molybdenum, and copper.

In the vicinity of Rodenhouse Wash, beryllium occurrences have been found in carbonate veins along quartzite bedding planes. Nolan (31) refers to this as the Climax mine area (fig. 25).

Beryllium occurs as the mineral bertrandite in grains about 10 microns in size. Grains may occur as clusters as much as 250 microns in size, but more often as individual grains. The bertrandite is in the quartz-carbonate veins and probably is associated with andalusite. Beryllium was also found in small pockets within the quartz monzonite east of the Climax mine and on a few of the many mine dumps dotting the western portion of the property.

In a portion of the Climax area known as the North section (fig. 25), beryllium is found over a length of 6,000 feet in a north-south direction, over a width of 1,000 feet in an east-west direction, and over a vertical range of 600 feet. The higher grade beryllium occurrences in the North section appeared to be confined to a 150-foot-wide strip along the eastern border of the quartzite and to a 100-foot-wide strip along the western border. Generally, where beryllium minerals were indicated, the rock had either a vuggy or sugary appearance with some slight limonite staining. The BeO content of samples collected from the North section ranged up to 0.30 percent; selected samples have contained as much as 1.56 percent BeO.

The South section is similar to the North section except the quartzite exposure is not as large (fig. 25). The South section is approximately 3,500 feet long, about 200 feet wide, and 300 feet high. An average content of 0.14 percent BeO was indicated for this area.

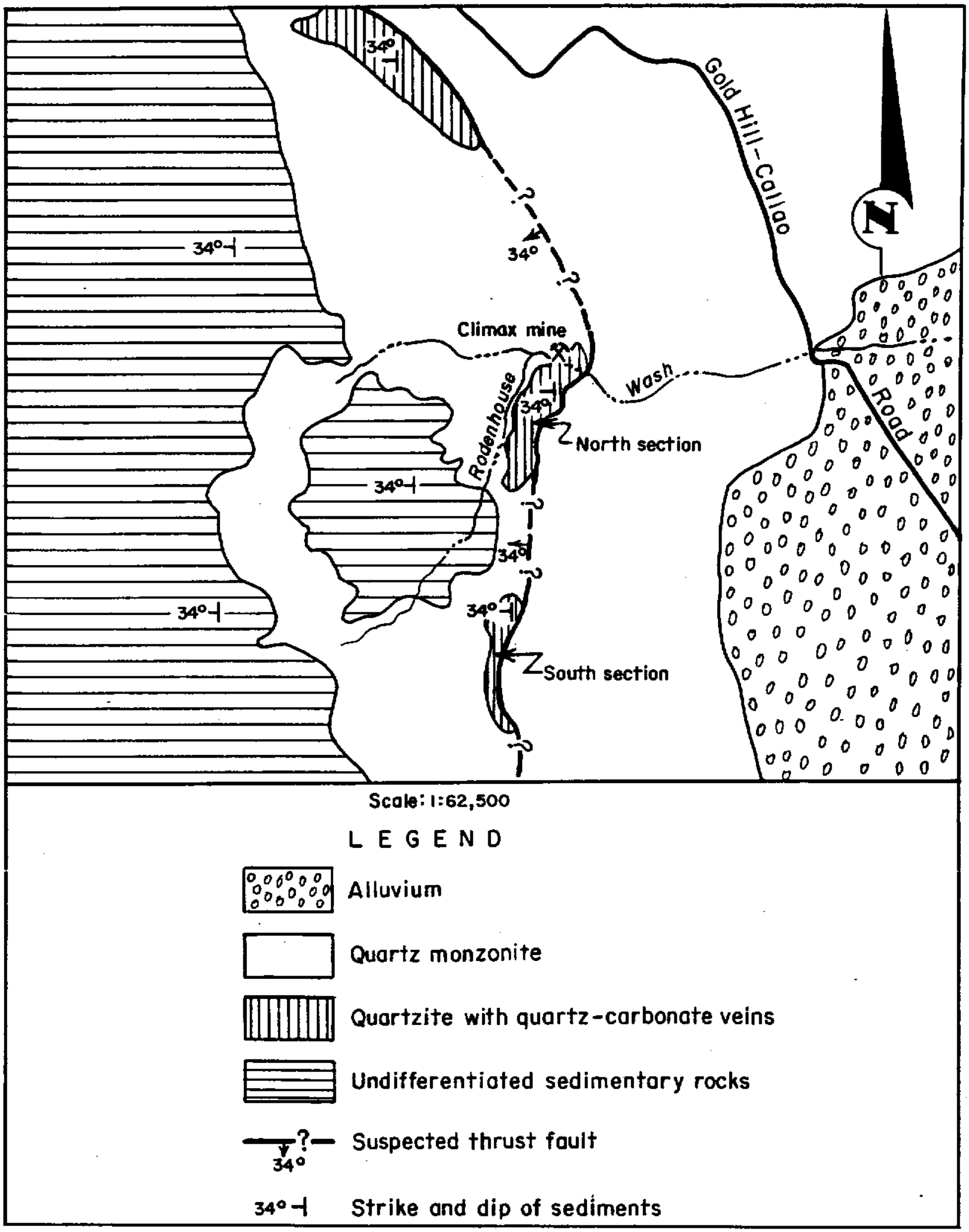

FIGURE 25. - Geologic Sketch Map of Part of the Vanguard Research Co. Property, Tooele County, Utah.

Development on the property consisted of the numerous prospect pits and trenches and the large- and small-scale mining done in previous years.

This deposit appears to have a significant tonnage potential for low-grade material that could be cheaply mined.

Other States

Other States included in the nonpegmatitic beryllium reconnaissance program were Nebraska, North Dakota, South Dakota, and Wyoming.

Nebraska--No samples were collected. Information from geologists was negative as to any occurrences of beryllium.

North Dakota--Samples of clay and lignite deposits tested in the laboratory gave essentially negative results.

South Dakota--A chemical analysis of 9.2 percent BeO was reported in one deposit. Examination of this deposit did not verify this assay.

Wyoming--The Bear Lodge mining district was examined on the basis of beryllium association with fluorspar. Samples collected gave up to 0.03 percent BeO by chemical analysis.

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APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
ARIZONA								
1. Abril mine....	Cochise...	Sec 34, T 17 S, R 23 E.	Cu, Pb, Zn, Mo.	Tactite between Paleozoic limestone and Tertiary granite (4).[3] Tactite contains helvite.	5 adits with drifts and raises.	0.01, 0, 0.15, 0, 0.005, 0.01, 0.	0.02 (composite)	Spectrographic analysis indicated presence of Li, Be, Cd, and Ga.
2. Beryl Hill (7 claims).	...do.....	SW¼NE¼ sec 23, T 14 S, R 28 E.	Be........	Beryl in quartz veins along biotite gneiss and porphyritic granite contact.	2 trenches.........	0.35, 0.56, 0.68, 0.18, 0.58, 2.63, 0.53.	-	Beryllium-bearing zone is small; potential appeared limited.
3. Gordon (San Juan) mine.	...do.....	Sec 10, T 18 S, R 23 E.[4]	Zn, Pb....	Tactites containing helvite between Paleozoic limestone and Tertiary granite (4).	-	0.03, 0.02, 0.03, 0.01, 0.07, 0.06, 0.07, 0.06.	.026 (composite)	Spectrographic analysis indicated presence of Li, Be, and Ga.
4. Johnson Co....	...do.....	Secs 23, 24, 25, 26, T 15 S, R 22 E.	Cu, Zn....	Replacement bodies in tactite and limestone.	-	0, 0.01, 0.01......	.002 (composite)	-
5. Little Lulu (23 claims).	...do.....	Secs 13, 14, 23, 24, 25, 26, T 20 S, R 27 E.	CaF, Be, Mn, Cu.	Metamorphosed limestone tactite and porphyritic granite.	2 opencuts, 3 pits, and bulldozer stripped area.	0, 0.03, 0.04, 14.7.	-	-
6. Mascot mine...	...do.....	NW¼NE¼ sec 21, T 14 S, R 27 E.	Cu........	Shear zones in Precambrian schist (4) intruded by granite.	3 adits with drifts and raises.	0, 0..............	-	-
7. Silver Drip (20 claims).	...do.....	Secs 14, 15, 22, 23, T 20 S, R 27 E.	Aquamarine	Aplitic dikes in porphyritic granite.	System of small trenches on dikes.	1.27...............	-	Gem stone deposit.
8. Texas Group (2 patented claims).	...do.....	SW¼NW¼ sec 18, T 17 S, R 31 E.	Cu, Ag, Pb, W.	Fault zones in tactite between limestone and quartz monzonite porphyry.	3 adits, 1 shaft, and several opencuts.	0, 0	-	-
9. Tungsten King (12 claims).	...do.....	Sec 6, T 16 S, R 22 E.	W, Be.....	Quartz veins along Precambrian schist and Tertiary granite (4) contact.	2 adits with crosscuts and drifts.	17 samples field-scanned.	-	Samples ranged to 3.50 percent BeO.
10. Thompson Beryl (5 claims).	...do.....	Secs 14, 23, T 20 S, R 27 E.	Aquamarine	Aplitic dikes in granite.	Small pits.........	Field scanning.....	-	Gem stone deposit.
11. Wakefield mine (15 claims).	...do.....	SW¼NE¼ sec 30, T 23 S, R 20 E.	Zn, Pb, Cu, W, Ag, Au.	Sedimentary rocks intruded by rhyolite and andesite.	905-ft adit with crosscuts, 500-ft adit with 70-ft winze, 65-ft shaft with 30-ft raise, 35-ft adit, inaccessible shaft, and numerous surface cuts.	0, 0..............	-	-
12. Apache mine...	Gila......	Sec 10, T 5 S, R 16 E.[4]	Mn........	Filled fractures in Gila Conglomerate (5).	4 large and several small opencuts.	0.012, 0	-	-
13. Breadpan Beryllium (fig. 7).	...do.....	T 9 N, R 12 E.....	Be, Cu, W.	Vein type deposits in Precambrian schist (21).	5 exploratory drill holes, 1 bulldozer trench, 1 open pit, and 5 opencuts.	Appendixes B and C.	-	28 samples collected by Bureau engineers ranged to 0.55 percent BeO.

14. Christmas mine.	...do.....	NW¼ sec 29, T 4 S, R 16 E.	Cu........	Cu segregations and veins in Precambrian rocks.	Shafts with underground workings.	0, 0.007..........	-	Important source of low grade Cu ore (38).
15. Cline WO_3 mine.	...do.....	SE¼SE¼ sec 13, T 5 N, R 9 E.[4]	W, CaF....	Small quartz veins in granite.	2 inaccessible shafts and numerous opencuts.	0.005, 0.005......	-	Small W producer.
16. El Oso mine...	...do.....	NE¼NE¼ sec 30, T 5 N, R 10 E.[4]	W, CaF....	.............do.............	235-ft adit with 200 ft of crosscuts, 1 inaccessible shaft, and several opencuts.	0, 0..............	-	Do.
17. Escondido mine.	...do.....	Sec 32, T 10 N, R 14 E.[4]	Fe, Mn, Cu, Pb, Zn, Ag.	Tactite zone between Precambrian Mescal Limestone (5) and intrusive gabbro.	55-ft shaft with 65-ft drift, and 2 large opencuts.	0.01..............	-	-
18. Fiber King....	...do.....	Sec 14, T 5 N, R 16 E.[4]	Asbestos..	Serpentinized Precambrian Mescal Limestone (5) intruded by diabase.	4 adits...........	0, 0..............	-	Idle--1962.
19. Gibson........	...do.....	Sec 21, T 1 S, R 14 E.[4]	Cu........	Fracture system in Precambrian Pinal Schist (5).	2 shafts (collars caved) and numerous surface cuts.	0, 0.01...........	-	Richest Cu producer in Arizona from 1900-12.
20. Hope mine.....	...do.....	SW¼SE¼SE¼SW¼ sec 19, NE¼SE¼ sec 30, T 6 N, R 14 E.	U.........	Fracture system in Precambrian Dripping Springs Quartzite (5) intruded by diabase.	4 adits and bulldozer cuts and trenches.	0.013, 0.02.......	-	Idle--1962.
21. Jones Beryllium Prospect.	...do.....	Sec 24, T 9 N, R 12 E.[4]	Be........	Alteration zone in Precambrian Alder Formation (21).	Small pit.........	0.01, 0.14, 0.087,	-	-
22. Jones Barite-Fluorite.	...do.....	SW¼SE¼ sec 20, T 9 N, R 13 E.	Ba, CaF, Cu.	Vein in zone between Precambrian Dripping Springs Quartzite (5) and altered diabase.	4 bulldozer trenches and 60-ft incline.	0, 0..............	-	Idle--1961.
23. Packard Fluorspar.	...do.....	Sec 16, T 6 N, R 11 E.	CaF.......	Fault zone in gneissic granite (16).	(16)..............	0, 0, 0...........	-	Idle--1962.
24. Snyder Property (3 claims).	...do.....	Sec 28, T 1 S, R 14 E.[4]	Cu........	Fault zones in granite intruding Precambrian Pinal Schist (5).	250-ft tunnel and 75-ft shaft with 65-ft drift.	0, 0..............	-	-
25. Walnut Creek..	...do.....	E½NE¼ sec 23, W½NW¼ sec 24, T 9 N, R 12 E.[4]	Be........	Alteration zone in Precambrian Pinal Schist (5), pegmatite in area.	None..............	0.005, 0.005, 0.007, 0.007, 0.01, 0.005, 0.005, 8 no BeO.	-	Area approximately 1 mile in extent along creek bed.
26. Westlake Tungsten (52 claims).	...do.....	Secs 7, 8, T 2 S, R 14 E.[4]	W, Pb, Cu.	Quartz veins in granite......	3 adits...........	0, 0, 0...........	-	Small tungsten producer.
27. Apache Tin (15 claims).	Graham....	Sec 31, T 7 S, R 30 E.	Sn, Fe....	Minerals in lower section of diversified rhyolites.	Surface cuts.......	-	.005	-
28. Black Beauty (3 claims).	...do.....	SE¼ sec 35, SW¼ sec 36, T 8 S, R 22 E.	W.........	Scheelite-bearing quartz-tourmaline veins in Precambrian schist (6) and granite.	Large opencut and several small surface cuts.	0.................	-	Idle--1963.
29. Twilight and Grey (22 claims).	...do.....	Sec 10, T 9 S, R 23 E.	-	Pegmatites in serpentinized Precambrian schist (6).	Several small adits and surface cuts.	0.27..............	-	-

See footnotes at end of table.

APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES--Continued

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
ARIZONA--Continued								
30. Daniels Camp..	Greenlee..	SE¼NE¼ sec 5, T 7 S, R 32 E.	CaF.......	Altered zone in andesite porphyry and breccia.	Large trench.......	0.................	-	Idle--1960.
31. Fourth of July.	...do.....	SE¼SW¼ sec 33, T 6 S, R 32 E, NE¼ NW¼ sec 4, T 7 S, R 32 E.	CaF, Mn...	Vein system in volcanics......	148-ft incline with drifts on 48-, 102-, and 148-ft levels. 102-ft level stoped to surface.	0.01..............	-	Do.
32. Lucky mines...	...do.....	SW¼SE¼ sec 3, NE¼ NW¼ sec 10, T 7 S, R 32 E.	CaF.......	Lenses in andesite and rhyolite dikes.	2 inclines with drifts.	0.01, 0...........	-	Do.
33. Ontario.......	...do.....	NE¼NE¼ sec 15, T 7 S, R 32 E.	CaF.......	Lenses along contact of andesite and intruded rhyolite.	2 100-ft shafts, large opencut.	0, 0..............	-	Do.
34. Polly Ann.....	...do.....	SE¼SW¼ sec 4, NE¼NW¼ sec 9, T 7 S, R 32 E.	CaF.......	Lenses in vein cutting andesite porphyry.	3 185-ft shafts with drifts and stopes.	0.................	-	Do.
35. Big Spar (2 claims).	Maricopa..	NE¼ sec 5, T 6 N, R 5 W.	CaF.......	Veins in granite.............	105-ft incline with 100-ft of drifting, several shallow shafts and surface cuts.	0.................	-	Do.
36. Flying Saucer (6 claims).	...do.....	Sec 12, T 6 N, R 6 W.	W.........	Porphyry dikes in granite...	-	0.................	-	-
37. Gold Cliff (4 patent claims, 9 unpatented claims).	...do.....	Sec 11, T 6 N, R 4 E.	W, Cu, CaF, Mo.	Pegmatite material in schist and granite.	Several adits and surface cuts.	0.................	-	-
38. Norps Group (6 claims).	...do.....	NE¼ sec 6, T 4 N, R 10 W.	Ba, CaF, Cu.	Quartz veins in contact along Precambrian schists (7) intruded by granite.	5 shafts and several surface cuts.	0.................	-	-
39. Tombstone (4 claims).	...do.....	Sec 18, T 4 N, R 9 E.[4]	W, CaF, Be.	Disseminations in granite.....	20-ft shaft and several surface cuts.	0.03, 0.036, 0.018, 0.02, 0.012, 0.002, <0.002.	-	Spectrographic analysis indicated presence of Li, Ru, Be, and Ga.
40. Boriana mine..	Mohave....	Secs 7, 18, 19, T 18 N, R 15 W secs 11, 12, 13, 14, T 18 N, R 16 W.	W, CaF, Be.	Lenses in small quartz veins in Precambrian phyllite (8).	Amounts to over 3 miles on 12 levels.	0.005.............	-	Premier W producer of Arizona.
41. Flo-Ber.......	Pima......	NW¼NW¼ sec 8, T 17 S, R 11 E.	CaF, Cu...	Veins in contacts along Precambrian schist intruded by Tertiary granite (9).	1 shaft, 4 adits, and several surface cuts.	0, 0..............	-	-
42. Fourteen Karat (Amargosa).	...do.....	SE¼NE¼ sec 19, SW¼NW¼, sec 20, T 18 S, R 12 E.	Cu, Au....	Altered area in quartzite intruded by granodiorite porphyry and diorite.	2 shafts and 2 inclines, inaccessible.	0.................	-	Idle--1963.

43. Copper Glance.	...do.....	NE¼NW¼ sec 6, T 18 S, R 13 E.	Cu........	Tactite zone between Paleozoic limestone and Tertiary granite (9).	675-ft shaft with levels at 160, 300, 400, 525, 625, and 675 ft.	0, 0..............	-	Idle--1961.
44. Gold King.....	...do.....	NE¼NE¼ sec 10, T 20 S, R 7 E.	Cu, Au, Mn.	Contact zones between Precambrian schist (9) and porphyry dikes.	Several inaccessible shafts and adits with drifts, and 2 new inclines.	0.................	-	Operating--1963.
45. Lesjimfre (Greenfield State Lease) (2 claims).	...do.....	NE¼NE¼ sec 4, T 21 S, R 7 E.	W, Be.....	Precambrian schist (9) intruded by pegmatite, porphyritic granite, and phonolite porphyry.[6]	45-ft shaft and 3 pits.	0.02, 0.15, 0.09, 0.07, 0.20, 0.09, 0, 0, 0.14, 0.07.	-	Beryllium-bearing vesuvianite.
46. New Cornelia, Well No. 1.	...do.....	SW¼NE¼ sec 24, T 11 S, R 6 W.	-	Extrusive volcanics..........	2 600-ft shafts....	0.................	-	Shafts sunk for domestic and industrial water. Produces 6,000 gpm. F reported in water.
47. Palo Verde and Mineral Hill mines.	...do.....	Secs 4, 5, T 18 S, R 15 E.	Cu........	Cu mineralization in tactite zones.	Shafts with underground workings and open trenches.	Field scanning negative.	-	(12).
48. Utah (2 claims).	...do.....	Sec 26, T 20 S, R 7 E.	Cu........	Tactite zone between silicified limestone and granite containing small pegmatites.	2 adits and a few surface cuts.	0.................	-	-
49. Black Butte (1 claim).	Santa Cruz	SE¼SE¼ sec 10, T 22 S, R 15 E.	Mn........	Breccia zone in phonolite porphyry.	Open trench with a 70-ft shaft in southern end with drifts and stopes.	0.................	-	-
50. Duquesne......	...do.....	SE¼SW¼ sec 2, T 24 S, R 16 E.[4]	Zn, Pb, Cu, Ag, Fe.	Cretaceous sedimentaries (9) intruded by granite. Complex faulting in both sediments and granite.	4 shafts with levels every 100 feet or less.	0.................	-	-
51. Mowry (21 patent claims).	...do.....	SW¼ sec 15, T 23 S, R 16 E.[4]	Mn, Pb, Ag.	Lenses in fault zone between Paleozoic limestone (9) and granite.	Numerous shafts, adits, trenches, and opencuts.	0, 0.006..........	-	-
52. Hillside mine.	Yavapai...	NE¼NW¼ sec 21, T 15 N, R 9 W.	Cu, Zn, Pb, Ag, Au.	Quartz veins in Precambrian mica schist (10).	16,000 ft of underground development from 765-ft shaft.	Mine 0, Tailings 0.08.	-	Production from 1887 to 1951 59,787 oz Au, 1,719,542 oz Ag, 64,367 tons Cu, 3,945 tons Pb, and 15,218 tons Zn (3).
53. Tungsten (18 claims).	...do.....	N½ sec 24, T 15 N, R 9 W.	W, Be, CaF, Bi, Mo.	Quartz veins filling shear zone in granite.	1,000-ft shaft, 500-ft shaft, 1,400 ft of drifts, and 5 shrinkage stopes.	0.07, 0.03	-	Mine now serves as a domestic water supply for Bagdad.
54. Black Bird (4 claims).	Yuma......	NE¼SE¼ sec 24, T 7 N, R 17 W.	Mn........	Shear zone in andesite porphyry and tuffaceous agglomerate.	Large trench.......	0.................	0.10	-

See footnotes at end of table.

APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES--Continued

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
ARIZONA--Continued								
55. Black Buck and Buckhorn (16 claims).	Yuma......	NE¼ sec 33, T 1 N, R 12 W.	Mn........	Gneissic granodiorite intruded by granite. Interbedded andesite and tuff northwest of property.	Several surface cuts.	0................	-	-
56. Black Crow....	...do.....	NE¼ sec 13, T 10 N, R 17 W.	Mn........	Contact zone between granitic gneiss and andesite.	Adit, incline, and trench.	0................	-	-
57. Black Diamond No. 1 (6 claims).	...do.....	SE¼ sec 19, T 2 S, R 22 W.[4]	Mn, Pb, Zn.	Shear zones in andesite porphyry.	Several adits, 3 open pits, and bulldozer stripping.	0................	-	Large Mn producer.
58. Black Mountain (4 claims).	...do.....	SW¼SE¼ sec 34, T 9 N, R 16 W.	Ba, CaF...	Veins in fracture zone between basalt and tuff.	8 trenches and 2 shafts.	0................	-	-
59. Blue Eagle (11 claims).	...do.....	Secs 18, 19, 20, T 5 N, R 12 W.	W.........	Quartz stringers in Precambrian schist and gneiss (11).	45-ft shaft, numerous adits and surface cuts.	0................	-	-
60. Burro Barite (8 claims).	...do.....	Sec 31, T 6 N, R 17 W.	Ba, CaF, Mn.	Lenses in fracture zone in volcanic agglomerate.	Surface cuts.......	0................	-	-
61. Castle Dome district.	...do.....	Secs 35, 36, T 4 S, R 19 W.	Ba, CaF, Pb, Zn.	Breccia zones in quartz monzonite.	Shafts, inclines, adits, trenches, and pits.	0, 0, 0, 0.02......	0.03	Small operations 1963.
62. Continental (Hardluck No. 1).	...do.....	SE¼NE¼ sec 10, T 10 N, R 17 W.	Cu........	Fracture zone between Precambrian phyllite (11) and andesite.	125-ft tunnel with a 75-ft drift and a 35-ft stope and surface cuts.	0................	.02	-
63. Golden Jack Pot.	...do.....	Sec 26, T 5 N, R 14 W.	W.........	Fractures in Precambrian schist and gneiss (11) near granite.	70-ft tunnel, 25-ft shaft, 30-ft shaft, and 4 pits.	0................	-	-
64. Hess, Hess, and Lilly (3 claims).	...do.....	NE¼NE¼ sec 4, T 3 S, R 23 W.	Mn........	Fault zone in interbedded tuff and andesite porphyry.	2 adits and sidehill cut.	0................	-	-
65. Mina de Mañana.	...do.....	SE¼ sec 26, T 2 S, R 23 W.[4]	Pb, Zn, Mn, Ba.	Fault zone in interbedded andesite porphyry and tuff.	4 adits, 2 inclines, and 3 shafts.	0................	.03	-
66. National Debt (4 claims).	...do.....	NW¼NW¼ sec 35, T 4 N, R 16 W.	Mn........	Fracture zone between tuff and tuffaceous agglomerate remnant in rhyolite porphyry.	Large trench and numerous small surface cuts.	0................	.02	-
67. Pay Day.......	...do.....	Sec 29, T 7 N, R 17 W.	Ba, CaF...	Quartzose veins in contact between granodiorite and porphyritic rhyolite.	Surface cuts.......	0................	-	-
68. Peggy "B" (2 claims).	...do.....	SE¼NW¼ sec 3, T 3 S, R 23 W.	Mn........	Fault zone in tuff and andesite porphyry.	2 trenches.........	0................	-	-
69. Red Chief (Barium) (21 claims).	...do.....	Sec 21, T 6 N, R 17 W.	Ba, CaF...	Fracture zones in agglomerate.	Surface cuts.......	0................	.03	-

70. Red Cloud.....	...do.....	SW¼SW¼ sec 2, T 4 S, R 23 W.[4]	Mn, Ba, CaF, Pb, Zn, Ag, W.	Fault zone in tuff, andesite porphyry, and rhyolite breccia overlying Precambrian schist intruded by granite and pegmatites.	525-ft shaft with levels at 270, 420, and 500 ft; stoped above 270 level; large trench.	0.................	-	Idle--1963.
71. Sand Gone.....	...do.....	NW¼NW¼ sec 3, NE¼NE¼ sec 4, T 8 N, R 16 W.	-	Fracture zones filled with granitic material in tuffaceous agglomerate.	2 small pits.......	0.................	-	Fracture zones have minor radioactive anomaly.
72. Sheep Tanks (14 patent claims, 61 unpatent claims).	...do.....	NW¼ sec 6, T 1 S, R 14 W, NE¼ sec 1, T 1 S, R 15 W.	Au, Mn, Ag, Pb,	Fault zone in complexly folded and faulted extrusive rocks.	Adits, tunnels, trenches, and pits.	0, 0, 0...........	.12	Idle--1963.
73. Squaw T (4 claims).	...do.....	Secs 26, 27, 34, 35, T 7 N, R 15 W.	W, Cu.....	Contact zone between roof pendants of Precambrian schist (11) and graphic granite.	3 pits, 1 trench with small adit, and 2 bulldozer cuts.	0, 0..............	.03	-
74. Three Musketeers (6 claims).	...do.....	Secs 24, 25, T 6 N, R 15 W.	W	Discontinuous quartz veins in schist and limestone near granite.	65-ft shaft, 110-ft shaft (both with drifting), tunnels 30 to 100 ft long, and surface cuts.	0.................	0	-
75. Turquoise mine.	...do.....	NW¼SE¼ sec 36, T 4 N, R 16 W.	Cu........	Filled fractures in rhyolite porphyry.	Shaft.............	0.................	-	-
76. Vampire mine..	...do.....	NE¼SW¼ sec 10, T 10 N, R 17 W.	Ba, CaF...	Fracture zone in andesite breccia.	20-ft tunnel and surface cuts.	0.................	-	-
77. White Christmas (7 claims).	...do.....	SE¼SE¼ sec 11, SW¼SW¼ sec 12, T 7 N, R 17 W.	Ba, CaF...	Filled fractures in andesite porphyry and tuff. Remnants of phyllite outcrop in area.	Trenches and pits..	0, 0..............	.04	-
78. White Rock....	...do.....	Sec 17, T 7 N, R 17 W.	Ba, CaF...	Filled fractures in interbedded rhyolite and andesite.	Trenches and bulldozer cuts.	0.................	-	-
				COLORADO				
1. Red Spruce mine (10 claims).	Boulder...	Sec 18, T 2 N, R 71 W.	-	Fissure in Precambrian schist.	400-ft shaft, 15-ft incline and tunnel.	0, 0..............	-	-
2. Brown's Canyon.	Chaffee...	Secs 22, 27, T 51 N, R 8 E, N.M.P.M.[6]	CaF.......	-	Mines and prospects.	[7]0................	-	-
3. Atlas (15 claims).	...do.....	Sec 19, T 51 N, R 7 E.[4] [6]	Be........	Beryllium minerals in vugs, miarolitic cavities, and blebs in Mount Antero Granite (1).	Small pits........	-	[8]10.00	-
4. California mine (3 patent claims).	...do.....	Sec 27, T 51 N, R 6 E.[4] [6]	Mo, Be, CaF, Ti.	Ore is in Mount Antero Granite (1).	50-ft incline, 90-ft crosscut, and 350 ft of drifts.	-	[8]10.00	-
5. CYAC (73 claims).	...do.....	Secs 23, 24, 25, 26, T 51 N, R 6 E.[4] [6]	Be........	Beryllium minerals in disseminated pods in altered Mount Antero Granite (25).	Large pit and trenches.	-	[8]10.00	-
6. Rico Argentine.	Dolores...	Secs 25, 26, 35, 36, T 40 N, R 11 W.[6]	-	-	-	0, 0..............	.05 .07	-

See footnotes at end of table.

APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES--Continued

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
				COLORADO--Continued				
7. El Paso Group (8 claims).	El Paso...	Sec 7, T 15 S, R 67 W.	Be, Ti....	Fracture zones in Pikes Peak Granite (15).	Pits and trenches..	Field scanning negative.	-	Beryllium enrichrichment is low.
8. St. Peters Dome (Comanche Group).	...do.....	Secs 13-17, T 15 S, R 67 W.	CaF.......	Veins in Pikes Peak Granite (15).	Shaft and opencut..	[9]0................	-	-
9. Big Dike Lode (3 claims).	Grand.....	NW¼SE¼ sec 2, N½SE¼ and NE¼NW¼ sec 3, T 4 N, R 78 W.	-	Fault zone in North Park Sandstone filled with diorite porphyry.	27-ft shaft........	0, 0, 0, 0, 0, 0...	0	Composite sample gave <0.01 percent Cb-Ta.
10. Cebolla Creek.	Gunnison..	T 46 N, R 1½, 2 W.[6]	Ti, Cb, Ta.	Magnetite, ilmenite, and perovskite in fractures of Precambrian pyroxenite stock.	6 diamond drill holes, surface cuts, and 4 adits.	0, 0, 0...........	.02 0 0	Spectrographic analysis indicated presence of Cs, Cb, Rb (22, 34).
11. Henson Mill...	Hinsdale..	Sec 34, T 44 N, R 4 W.[4 6]	-	-	-	0.................	-	-
12. Northgate District.	Jackson...	T 11 N, R 79 W.	CaF.......	Veins in Precambrian granite and schist.	Tunnels and surface cuts.	0, 0, 0...........	.005 .007 .027	-
13. Challenger....	Larimer...	Secs 22, 23, T 8 N, R 72 W.	Be........	Fissure zone in Precambrian mica schist.	Trench and pits....	0, 0.02...........	-	-
14. Wagon Wheel Gap.	Mineral...	Secs 1, 2, T 40 N, R 1 E.[6]	CaF.......	Veins in rhyolite and andesite.	-	0, 0..............	.03 .03	-
15. A & C (2 claims).	Park......	E½ sec 5, T 11 S, R 72 W.	Be........	Greisen in granite...........	50-ft tunnel and surface cuts.	6.58..............	-	-
16. Boomer mine (2 patent claims, 16 unpatent claims).	...do.....	SW¼ sec 21, T 11 S, R 72 W.	Be, Ag, Cu, Pb, CaF.	Greisen along contact of pegmatite and mica schist.	105-ft shaft with levels at 30, 50, 65, and 105 ft. 500-ft drifts and 150-ft raises, some to surface. 219-ft shaft.	9.7, 2.27, 0.005, 2.27, 1.68, 0.04, 2.04, 0.11, 0.04, 0.04, 1.21, 0.43, 3.30, 0.12, 0.25, 0.25, 2.38, 2.30, 0.34, 0.06, 3.58, 3.56, 10.92, 0.19, 0.02, 0.78, 1.93, 16.05, 11.0, 33 no BeO.	-	-
17. Guernsey Gulch (4 claims).	...do.....	S½ sec 17, T 7 S, R 75 W.	CaF.......	Filled veins in granite.......	Opencut and trench.	0.................	-	-
18. Hazel Marie (4 claims).	...do.....	Secs 4, 5, T 11 S, R 72 W.	Be........	Beryllium minerals in greisen in Pikes Peak Granite.	2 shafts and surface cuts.	8.60, 8.50, 6.00...	-	Greisen is discontinuous in shear zones over short distances.
19. Little John (4 claims).	...do.....	Sec 22, T 11 S, R 72 W.	Be, W.....	En echelon beryl-quartz veins in biotite gneiss.	25-ft shaft........	-	-	Beryl restricted to 1½-inch-wide discontinuous zones.

20. American and Terry Tunnels (Sunnyside mine).	San Juan..	Sec 28, T 42 N, R 7 W.[4,6]	Mn, Be....	Rhodonite-helvite deposits in Silverton Volcanics.	Tunnels with workings.	0, 0, 0, 0, 0, 0, 0, 0.03, 0.20.	-	-
21. Comanche......	Teller....	Sec 13, T 15 S, R 68 W.	Be........	Shear zones in Pikes Peak Granite near Mount Rosa Granite (15).	Large surface cut and drill holes.	6.43, 0...........	-	Beryllium erratic and discontinuous.
22. Tracy (3 claims).	...do.....	Sec 6, T 15 S, R 68 W.	Be, Th, R.E.	..............do..............	Bulldozer stripping.	1.21, 0.78, 0, 0...	-	Beryllium is sparse.
				New Mexico				
1. Moore.........	Bernalillo	Sec 6, T 9 N, R 5 E.	CaF, Pb...	Fissures and breccia zone in quartzite near granite.	Adit and pits......	0.................		-
2. Organ district.	Dona Ana..	T 22-23 S, R 3-4 E.	Zn, Pb, Cu, W.	Replacement bodies averaging 4 ft thick near base of Lake Valley Limestone series.	Varied type mining.	[10]0................	-	-
3. Grandview mine.	Grant.....	Secs 26, 35, T 16 S, R 9 W.	Pb, Zn, Cu.	Replacement bodies in tactite.	Old stope and 3 adits.	0.................	0.014	-
4. Baker Standard (4 claims).	Hidalgo...	Secs 26, 27, T 25 S, R 21 W.	W.........	Scheelite in tactite zone filling fault and shear zone in limestone.	30-ft shaft with 30-ft drift, and 3 shafts.	0.................	-	-
5. Irish Rose....	Luna......	Sec 29, T 24 S, R 12 W.	W, Be.....	Quartz-wolframite vein with sparse beryl in micaceous selvage.	Shaft, trench......	0.08 (hanging wall) 0.14 (footwall).	.002 (dump)	-
6. Tungsten Hill.	...do.....	NW¼ sec 29, T 24 S, R 12 W.	Pb, Zn, Be.	Helvite in tactite zone in Permian limestone.	80-ft shaft, 20-ft shaft, and surface cuts.	0.................	.024	-
7. Cornudas Mountains.	Otero.....	Tps. 25, 26, 27 S, Rs 13, 14 W.	-	Nepheline syenite intrusions in Permian-Pennsylvanian sediments (40).	Shafts, trenches, bulldozer cuts, and pits.	25 samples 0 to 0.20	.002 .007 .01	Spectrographic analysis indicated presence of Sn, Ni, Rb, and Li.
8. San Pedro Copper (17 patent claims, 4 unpatent claims).	Santa Fe..	Secs 21, 22, 27, 28, T 12 N, R 7 E.	Cu, W.....	Contact metamorphic bodies in limestone.	Unknown. Remains of 3 smelters and 1 mill.	-	.02 .02 (mine dump slag).	Production of 20 million tons of copper since 1889.
9. Turquoise Pits.	...do.....	Sec 5, T 14 N, R 8 E.	Turquoise.	Veinlets and stringers in altered quartz monzonite.	Several pits.......	0.................	-	-
10. Alamo.........	Sierra....	Secs 15, 16, T 17 W, R 4 W.	CaF.......	Fissures in shattered limestone.	1 shaft and several pits.	0.................	-	-
11. Lake Valley mine (13 patent claims).	...do.....	Secs 20, 21, T 18 S, R 7 W.	Mn, Ag....	Irregular replacement bodies in cherty Mississippian limestone fault block in rhyolite, andesite, and monzonite porphyry.	Shafts and inclines with several miles of underground workings and surface cuts.	0.................	-	Large Ag and Mn producer. Non-operating--1961.
12. Universal (1 of 10 claims).	...do.....	Sec 22, T 14 S, R 4 W.	CaF, Mn...	Veins in granitic and gneissic Cabolia Mountain intrusive. Small pegmatitic masses present.	50-ft shaft, 120-ft tunnel, and surface cuts.	0, 0, 0.005, 0.02..	-	Beryl reported; none found in pegmatites.

See footnotes at end of table.

APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES--Continued

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
NEW MEXICO--Continued								
13. Iron Mountain (10 claims).	Socorro...	Sec 35, T 9 S, R 8 W.	CaF, W, Be, Fe, Mn.	Ribbon rock tactites containing helvite, danalite, and other Be minerals.	-	0.002, 0.18, 0.08, 0.15, 0, 0, 0.	-	(25, 37).
14. Manganese Corp. of America (6 claims).	...do.....	Secs 17, 18, T 4 S, R 1 W.	Mn........	Fracture zones in porphyritic rhyolite.	Surface cuts.......	0.05..............	-	-
15. Warm Spring Deposit.	...do.....	Sec 6, T 9 S, R 7 W.	Be........	Fault zone in altered rhyolite-tuff agglomerate in rhyolite (41).	7 trenches and 18 drill holes.	1.60, 0.65, 0.33, 0.29, 0.17, 2.00, 0.83, 0.25.	-	-
SOUTH DAKOTA								
Lauretta (3 claims).	Custer....	Sec 12, T 5 S, R 4 E.	Be........	Filled fractures in shattered micaceous schist.	60-ft shaft, 30-ft opencut, and pits.	-	9.2 .01 .005	Spectrographic analysis indicated Cs and Rb.
UTAH								
1. Cougar Spar (3 patent claims, 5 unpatent claims).	Beaver....	Sec 10, T 30 S, R 18 W.	CaF.......	(19).........................	(19)..............	0, 0..............	-	-
2. Cove Creek Deposit (114 claims).	...do.....	Tps 25, 26 S, Rs 6, 7 W.	S, CaF....	Impregnated fresh to altered rhyolite, tuff, and limestone.	Surface cuts and some underground openings.	0..................	-	-
3. Creole, Harriet, and Lincoln mines (7 claims).	...do.....	Creole NW¼NW¼ sec 29; Harriet NE¼NW¼ sec 29; Lincoln NW¼SE¼ sec 20, T 29 S, R 9 W.	Cu, Zn, Au, Ag, Pb.	Tactite zones in limestone near granite sills and dikes.	Inclines, tunnel, raises, and stopes.	Field scanning negative.	-	-
4. Evans and Sullivan.	...do.....	SW¼SE¼ sec 31, T 28 S, R 8 W.	W.........	Tactite zone between limestone and granite.	2 shafts and surface cuts.	-	.03	Spectrographic analysis indicated presence of Be, Cs, Ga, Li, and Rb.
5. Miller mine (30 claims).	...do.....	NE¼NE¼ sec 20, T 28 S, R 8 W.	W, Be.....	Tactite zone between faulted limestone and granite.	130-ft shaft, 122-ft incline, and surface cuts.	0.97, 1.62, 0.82, 0.28, 0.34, 6.21, 4.88, 0.07, 0.83, 0.31, 6.10, 6.22, 0.18, 0, 0, 0.027, 7.6, 0,012.	-	-
6. Miller Prospect.	...do.....	Sec 23, T 30 S, R 7 W.	-	Altered rhyolite............	Pit................	-	.02	Spectrographic analysis indicated presence of Be, Cs, Ga, Li, and Rb.
7. Shotwell......	...do.....	NE¼NW¼ sec 21, T 28 S, R 6 W.	U, Mn.....	Alteration zone in rhyolite and dacite.	Surface cuts and drill holes.	0.01, 0, 0.025.....	-	-

8. Staats Fluorspar (9 claims).	...do.....	Sec 25, T 29 S, R 16 W.	CaF, U....	Fault zone in limestone intruded by dacite porphyry flows.	4 Shafts and 2 tunnels interconnected and surface cuts.	Field scanning negative.	-	-
9. Rainbow (6 claims).	Iron......	Sec 19, T 32 S, R 14 W.[4]	Mn, W.....	Shear zones in rhyolite flows.	Bulldozer cut......	0.019.............	-	-
10. Tuff beds...	...do.....	Sec 11, T 33 S, R 19 W.[4]	-	Tuff beds between rhyolite flows.	None..............	0.019.............	-	-
11. Apex Tungsten (4 patent claims, 20 unpatent claims).	Juab......	Secs 20, 21, T 12 S, R 18 W.	W, CaF, Be.	Metamorphosed sediments cut by series of faults near granite and porphyritic intrusions.	Shaft and incline with underground workings, surface cuts, and 18 drill holes.	See figure 23......	-	Operating--1962.
12. Bell Hill (4 claims).	...do.....	Sec 11, T 13 S, R 12 W.	-	Flat-lying beds of rhyolite and rhyolite tuff.	None..............	0.................	-	-
13. Blue (6 claims).	...do.....	Sec 4, T 13 S, R 12 W.	-	Rhyolite breccia plugs intruded in limestone.	Surface cuts and drill holes.	-	-	-
14. Blue Chalk (22 claims).	...do.....	Sec 9, T 13 S, R 12 W.	Be........	Rhyolite tuff between dolomite and rhyolite.	Bulldozer surface cuts.	0.78, 0.01, 0.24, 0, 0.04, 0.23, 1.28, 0.49, 0.18.	-	-
15. Clay Bank (2 claims).	...do.....	Sec 35, T 12 S, R 12 W.	Be........	Rhyolite tuff exposed by fault in contact with dolomite.	Sidehill cut.......	0.20..............	-	-
16. Desert Tungsten.	...do.....	Secs 32, 33, T 11 S, R 5 W.	W, Cu, Pb, Zn, Ag.	Paleozoic limestone intruded by Tertiary monzonite, granite, and diorite (42).	Trenches, drill holes, shafts, and inclines.	0, 0, 0, 0.........	0.03	-
17. Dugway Dell...	...do.....	Sec 35, T 12 S, R 12 W.	Be........	Opaline fluorite nodules in clayey tuff between limestone and rhyolite.	Surface cuts.......	Up to 4.0, av. 0.50	-	-
18. Honeycomb Hills.	...do.....	Sec 12, T 13 S, R 16 W.	U, Be.....	Topaz-bearing rhyolite plugs intrude tuffaceous agglomerate.	Tunnels, surface cuts, and 3 drill holes.	0.21, 0.50, 0.12, 0.11, 0.05, 0.06, 0.02, 0.02, 0.01, 0.01, 0.01, 0.01, 0.003, 1.20, 2.00, 0.41, 0.97, 1.55, 1.30, and 10 no Be	-	Spectrographic analysis indicated presence of Cs, Cb, and Rb.
19. Jeannie (8 claims).	...do.....	Sec 23, T 12 S, R 12 W.	-	Flat-lying welded rhyolite tuff.	None..............	0.................	-	-
20. Roadside (5 claims).	...do.....	Secs 5, 8, T 13 S, R 12 W.	Be........	Rhyolite tuff between dolomite and rhyolite.	Bulldozer surface cuts.	0.02, 0.90, 0......	-	-
21. Taurus (10 claims).	...do.....	Sec 32, T 12 S, R 12 W.	Be........	............do.................	........do.........	1.0, 2.43, 4.0.....	-	-
22. Trout Creek (6 patent claims, 3 unpatent claims).	...do.....	Sec 28, T 12 S, R 18 W.	CaF, W, Zn, Be.	Replacement zone in limestone member of Prospect Mountain Quartzite.	Shafts, inclines, surface cuts, and tunnel with drifts, raises, and stopes.	0.50, 6.61, 0.80, 0.16.	-	-
23. Yellow Chief..	...do.....	Sec 35, T 12 S, R 12 W.	U.........	Rhyolite tuff.................	Large open pit.....	Field scanning negative.	-	-

See footnotes at end of table.

APPENDIX A. - PROPERTIES INVESTIGATED FOR NONPEGMATITIC BERYLLIUM OCCURRENCES--Continued

Property	County	Location	Principal commodity	Type of deposit	Development	BeO, percent		Remarks
						Detector[1]	Chemical[2]	
UTAH--Continued								
24. King Manganese.	Kane......	Sec 2, T 42 S, R 3 W.	Mn........	Nodules scattered in shale bed in sandstone.	Surface cuts.......	0.................	-	-
25. Cedar Hill....	Tooele....	Sec 19, T 8 S, R 12 W.	-	Welded rhyolite tuff and agglomerate.	None...............	0.................	-	-
26. Consolidated Mercur.	...do.....	Secs 5, 6, 7, 8, T 6 W, R 3 W.	Au........	Carbonaceous shales and limestone.	Numerous and varied types mine workings.	10 no BeO, 0.002...	0.05	Idle--1962.
27. Eagle (4 claims).	...do.....	Sec 31, T 8 S, R 11 W.	-	Obsidian flow capped by rhyolite tuff.	Surface cuts.......	0, 0, 0, 0, 0.01, 0.007, 0.002, 0.01.	-	-
28. Halladay Cinnabar.	...do.....	Secs 2, 11, T 2 S, R 7 W.	Hg........	Breccia zone in Paleozoic limestone.	2 100-ft shafts, 150-ft tunnel with stopes to surface, and open pit.	0.03, 0, 0, 0......	-	-
29. Old Joe.......	...do.....	Sec 7, T 8 S, R 12 W.	-	Rhyolite, obsidian, rhyolite breccia, and rhyolite tuff exposures.	5-ft tunnel........	0, 0, 0, 0, 0......	-	-
30. Sheeprock Mountains.	...do.....	Secs 21, 22, 23, 26, 27, 33, T 10 S, R 6 W.	Be........	Disseminated beryl crystals in granite.	3 tunnels and and surface cuts.	0.02, 0.005, 0, 0,	-	-
31. Utah Bunker Hill (26 claims).	...do.....	Sec 14, T 2 S, R 7 W.	Hg, Au....	Quartz veins in Paleozoic limestone intruded by granodiorite.	.........do........	0, 0, 0, 0.........	.02	-
32. Vanguard Research (23.48 square miles.	...do.....	Tps 8, 9 S, Rs 17, 18 W.	Be, Au, Ag, Pb, Zn, As, Mo, Cu.	Carboniferous sediments complexly block- and thrust-faulted near quartz monzonite intrusion (31).	Surface cuts and old mines.	0, 0.04, 0.095, 0.19, 0.095, 0.06, 0.30, 0.06, 0.17, 0.07, 0.16, 1.56.	-	Prospecting--1963.
33. Iron King.....	Utah......	SE¼NW¼ sec 21, T 10 S, R 2 W.	Mn, Zn....	Fault zones in limestone and rhyolite.	Shaft and surface cuts.	0	-	-
34. Tip Top.......	...do.....	NW¼NW¼ sec 9, T 10 S, R 2 W.	Mn, Zn....	Fault zone in limestone.......	Shaft, tunnels, and surface cuts.	0.005.............	.02, 0	-
WYOMING								
Bear Lodge District (22 claims).	Crook.....	Secs 15, 22, 23, T 52 N, R 63 W.	CaF.......	Replacement deposits in Mississippian limestone.	Surface cuts, shafts, and tunnels.	-	0.03	Spectrographic analysis indicated presence of Be, Cs, Ga, Li, and Rb.

[1]Each figure represents an assay on a separate sample; assays determined with the laboratory detector.
[2]Number of samples and result of chemical analysis.
[3]Numbers in parentheses refer to numbers in the preceding bibliography.
[4]Approximate; unsurveyed township.
[5]Identification uncertain.
[6]New Mexico principal meridian. All other townships in Colorado referred to sixth principal meridian.
[7]Composite of 6 samples.
[8]Composite average of 21 samples.
[9]Composite average of 7 samples.
[10]Composite average of 10 samples.

APPENDIX B. - ANALYSES OF DRILL HOLE CUTTINGS,
BREADPAN AREA, GILA COUNTY, ARIZ.

Sample interval, feet	Equivalent BeO, percent	Sample interval, feet	Equivalent BeO, percent
DRILL HOLE 1			
0-12	0.02	60- 62	0.12
12-16	.21	62- 66	.085
16-18	.068	66- 68	.21
18-20	.73	68- 70	.12
20-24	.05	70- 76	.068
24-26	.073	76- 78	.01
26-30	.10	78- 86	.045
30-34	.06	86-114	.01
34-36	.01	114-144	.022
36-44	.035	144-148	.035
44-46	.085	148-154	.015
46-60	.039		
DRILL HOLE 2			
0-14	0.012	38- 56	0.011
14-18	.05	56- 58	.095
18-36	.011	58- 72	.005
36-38	.065		
DRILL HOLE 4			
50-60	0	60- 62	0.038
DRILL HOLE 5			
0- 2	0	44- 50	0.028
2- 4	.033	50- 52	0
4- 6	.016	52- 54	.035
6- 8	.057	54- 56	.017
8-18	.017	56- 58	.076
18-20	0	58- 60	.025
20-24	.031	60- 62	.012
24-28	.004	62- 64	.033
28-34	.032	64- 66	.008
34-36	.007	66- 68	.043
36-38	.032	68- 70	.023
38-44	.016	70 -80	.031
DRILL HOLE 6			
0- 4	0	62- 64	0.04
4-12	.024	64- 66	0
12-20	0	66- 68	.024
20-22	.02	68- 74	0
22-24	0	74- 76	.024
24-40	.033	76- 82	0
40-42	.07	82- 84	.026
42-52	.004	84- 88	.01
52-54	.033	88-106	0
54-58	0	106-110	.015
58-60	.026	110-132	0
60-62	0		

APPENDIX C. - ANALYSES OF SURFACE SAMPLES ON BREAD PAN 1, GILA COUNTY, ARIZ.

Location	Sample description	BeO, percent
Trench exposure:[1]		
0 ft..........	Edge of pit......................................	0.021
8 ft..........	Limonitic stained schist with small feldspathoidal seam.	.045
20 ft..........	12-inch feldspathoidal seam perpendicular to strike of schist.	.15
110 ft..........	Schist with slight limonite stain.................	0
220 ft..........	2-inch seam of feldspathoidal alteration with slight limonite staining in schist.	0
235 ft..........	15-inch seam of altered limonite-stained schist with some feldspathoidal alteration in the center of seam.	.012
242 ft..........	18-inch seam of limonite-stained altered schist with feldspar and quartz in center of seam.	.087
270 ft..........	27-inch seam of limonite-stained slightly feldspathoidal schist.	.04
Pit exposure:[2]		
-	Cuttings from percussion drill hole 6 feet southwest of drill hole 1.	.195
-	16-inch veinlet oblique to foliation in pit at drill hole 1 (quartz, garnet, fluorspar, tourmaline, and magnetite contained also).	.55
North wall......	-	.021
East wall.......	-	.045
South wall......	-	.027
West wall.......	-	.047

[1]Figures represent distances north of pit at drill hole 1.
[2]Pit at drill hole 1.